UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

RESEARCH PROJECT

# ASSESSMENT OF PRACTICES AND STRATEGIES FOR WASTE MANAGEMENT OF CONCRETE AND CEMENTITIOUS MATERIALS IN SOUTH AFRICA

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A research report submitted to the Faculty of Engineering and the Built Environment, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Science in Engineering

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**DECLARATION**

I declare that this research report is my own unaided work. It is being submitted to the Degree of Master of Science to the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination to any other University.

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(Signature of Candidate)

...21... day of ...OCTOBER... year...2020... in...SANTIAGO, CHILE...

## ABSTRACT

In 2017 the construction and demolition sector of South Africa produced approximately 14 million tonnes of waste. This includes concrete and cementitious waste. In South Africa, there are waste management strategies in place that aim to: (a) discourage high levels of waste disposal on landfills, (b) encourage a decrease in waste production, and (c) guide how to manage the waste produced. However, there is a poor understanding of the link between these strategies and what is being practised on construction sites. This study was conducted in South Africa, Gauteng province, to examine the practices and strategies for waste management of concrete and cementitious material. The assessment was conducted through literature review and visits to five active construction sites where data was collected through oral interviews, observation of site activities and questionnaire distribution to the workers on site.

The results of the research demonstrate that practitioners are aware of the traditional waste hierarchy, however, they need to adopt the latest waste hierarchy outlined in the State of Waste Report. This is because they still resort to disposing waste on landfill before exploring all possible options on the waste hierarchy model. The waste management plans developed on construction sites accommodate getting rid of waste material from the site but they do not clearly define how this can be done while avoiding disposal on landfill. The study has also shown that there is inadequate information on waste concrete and cementitious material quantities. Practitioners on site are of the opinion that there is insufficient government intervention with waste management and also lack knowledge on possible incentives offered. Though there is limited information on concrete and cementitious waste material, practitioners do think it is important to have efficient waste management plans in practice.

The study recommends that the government outlines policies and legislation that encourage practitioners to record quantities of different types of waste produced on construction sites to improve the data available in South Africa. The policies and strategies should also require Environment, Health and Safety practitioners to submit annual waste reports on their construction projects. More studies should also be conducted in South Africa concerning concrete and cementitious waste, to understand how it is managed and to know how much of it ends up disposed on landfill.

## DEDICATION

I dedicate this research report to my parents Mmamorongoa Mogodi and Ramaoto Mogodi, the great pillars in my life, for their constant support and contribution towards my education.
This research report is in memory of my late grandmother Matsie Thosago.

**ACNKOWLEDGEMENTS**

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**LIST OF ABBREVIATIONS**

C&D = Construction and Demolition
CBD = Central Business District
DEA = Department of Environmental Affairs
DSEWPaC = Department of Sustainability, Environment, Water, Population and Communities
ECA = Environment Conservation Act
EU = European Union
EMI = Environmental Management Inspector
EHS = Environment, Health and Safety
FTE = Full Time Equivalent
GHG = Greenhouse gas
HSE = Health Safety and Environment
NWF = National Waste Forum
NWMS = National Waste Management Strategy
NAMA = Nationally Appropriate Mitigation Action
NEM: WA = National Environmental Management: Waste Act
NSFD = National Framework for Sustainable Development
NSSD = National Strategy for Sustainable Development
PWF = Provincial Waste Fora
SA = South Africa
SoWR = State of Waste Report
UTM = Universal Transverse Mercator
WMCR = Waste Classification and Management Regulations
WMO = Waste Management Officer
WMP = Waste Management Plans

# CHAPTER 1: INTRODUCTION

## 1.1. Background

All over the world, there are plans to work towards going ´green´ through the well-known and controversial term ´sustainability´. This is because, among other reasons, humans perceive sustainability as a way to conserve human nature (Tosic, Marinkovic and Stojanovic, 2017). South Africa (SA) is sharing a similar goal and hence it is deemed necessary to implement tools (policies, programs, and incentives) as a strategic approach to assist in governing sectors of the economy. The country aims to promote a green economy whilst concurrently achieving its development goals through its commitment to executing the Nationally Appropriate Mitigation Action (NAMA). The goals include; reaching a 34 per cent deviation below the ´business as usual' emissions growth trajectory by 2020 and a 42 per cent deviation below the ´business as usual´ emissions growth trajectory by 2025 (DEA, 2015).

SA´s promotion of sustainability can be seen through initiatives such as:

1. National Framework for Sustainable Development (NSFD) which aims to "express the national vision for sustainable development and indicate strategic interventions to re-orientate South Africa´s development path in a more sustainable manner" (DEA, 2012a).
2. National Strategy for Sustainable Development (NSSD) which "identifies five strategic interventions required to achieve the nation's vision for sustainable development" (DEA, 2012a) and summarises the strategies as follows:
    - Enhancing systems for integrated planning and implementation
    - Sustaining our ecosystems and using natural resources efficiently
    - Towards a green economy
    - Building sustainable communities
    - Responding effectively to climate change

The construction sector plays an important role in working towards the country´s goals of developing a green economy for example through management of construction waste. In 2017 the waste sector in South Africa produced around 107.8 million tonnes of waste (DEA, 2018).

The National Environmental Management: Waste Act (NEM: WA) defines waste as (DEA, 2011):

*Any substance, whether or not that substance can be reduced, reused, recycled and recovered –*

a) *that is surplus, unwanted, rejected, discarded, abandoned or disposed of;*
b) *which the generator has no further use of for the purposes of production;*
c) *that must be treated or disposed of; or*
d) *that is identified as a waste by the Minister by notice in the Gazette, and includes waste generated by the mining, medical or other sector; but –*

i. *a by-product is not considered waste; and*
ii. *any portion of waste, once re-used, recycled and recovered, ceases to be waste;*

Since the definition of waste excludes that of by-products, the Waste Act goes further and defines by-products as follows:

*By-product means a substance that is produced as part of a process that is primarily intended to produce another substance or product and that has the characteristics of an equivalent virgin product or material.*

NEM: WA categorises waste into two groups, namely general waste & hazardous waste and defines them as follows (DEA, 2011):

- General waste - waste that does not pose an immediate hazard or threat to human health or the environment.
- Hazardous waste - any waste that contains organic or inorganic elements or compounds that may, owing to the inherent physical, chemical and toxicological characteristics of that waste have a detrimental impact on health and environment.

Given that South Africa is a country promoting sustainability, the management of waste produced should be interrogated, analysed and refined where necessary.

## 1.2. South African construction industry

The construction sector is one of the biggest economic drivers´ particularly in developing countries and South Africa is of no exception. This is because the government develops the country´s economy by investing in physical infrastructure, and the main task of the construction industry is to provide infrastructure for human daily activities (Marx, 2014). A growing economy directly affects the construction sector and this can be "measured by the rate of physical infrastructure development such as roads, bridges, harbours and buildings" (Dithebe *et al.*, 2018). A survey conducted by Blueprint group reports that in South Africa the construction industry employs "approximately 1.46 million people, including 1 million in the formal construction industry and 460,000 in the informal construction industry" (Blueprint Group, 2017). Between the years 2009 and 2018 the construction industry has generated up to 255 000 jobs in the country, being among the top eight industries to play a part in job creation (CIDB, 2018).

Given that construction plays an important role in the country´s economy, it is essential to understand components that shape and affect the construction industry. This is important for the purpose of the study because it provides better understanding for integration and promotion of sustainable development in the construction industry, which includes management of concrete and cementitious waste. A study by (Dithebe *et al.*, 2018) shows factors that influence the performance of the construction industry in South Africa to include the following:

- Financial factors - instability of construction material, project cost overrun, backlogs of payment to contractors, material and equipment, budget updates for construction, exchange rates, cost control system, income inequality
- Time-related factors - deficiency of skills, access to construction material, importing construction services
- Productive factors - availability of equipment, limited scale of construction project, project complexity.
- Regulation factors - planning permissions and control, skills development, employment and labour practices, black economic empowerment.
- Human resource factors - competitive salary, and employee motivation. Incapacity to spend funds received on construction projects.

Looking at these factors highlighted above, construction material is one of the items that directly affects financial and time-related factors making it one of the important aspects to explore in influencing the construction industry.

### 1.3. Waste and waste management in the South African construction sector

As per the categories made by NEM: WA[1], 107.8 million tonnes of waste generated in 2017 were composed of 42 million tonnes of general waste, 38 million tonnes of hazardous waste and 27.8 million tonnes of unclassified waste. The general waste group incorporates; domestic waste, building and demolition waste, business waste, and inert waste (DEA, 2012b). The general waste composition shown in **Figure 1** illustrates the breakdown of these divisions.

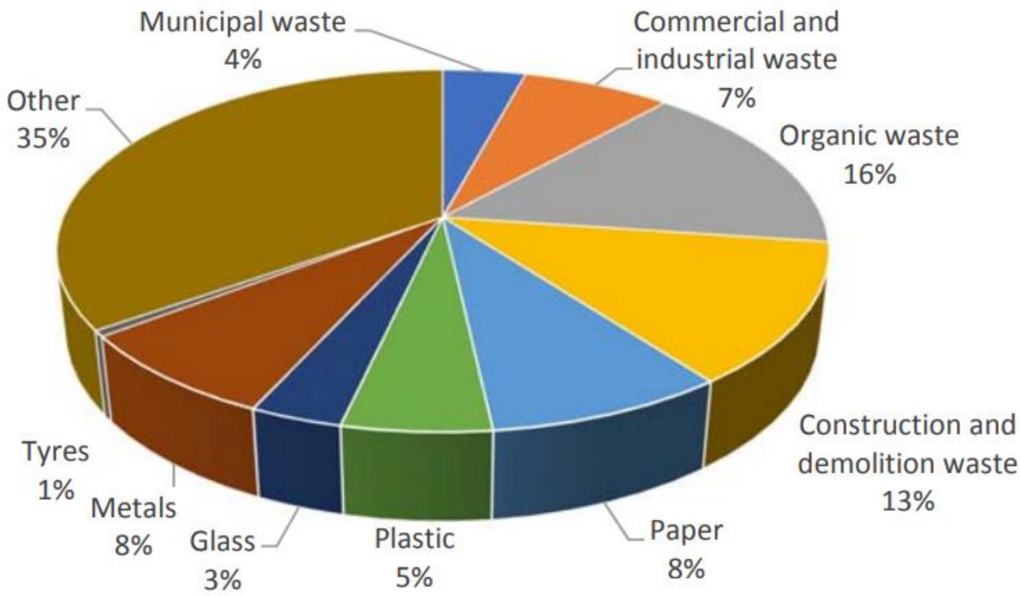


**Figure 1:** Breakdown of general waste generated in 2017 (DEA, 2018)

Construction and Demolition (C&D) waste can be in various forms such as; metals, bricks, masonry, ceramics, concrete, plastic, paper, timber, glass and excavation materials (DEA, 2012b). It is the third-largest contributor under the general waste group as highlighted in **Figure 1**.

A study conducted by the World Business Council for Sustainable Development (WBCSD) reports that "concrete is the second most-consumed material in the world after water" (WBCSD, 2009). More research on concrete is needed because there is no evidence demonstrating a possible decline in its use (Muigai et al., 2013).

[1] General waste and hazardous waste (see chapter 1, section 1.1)

## 1.4. Research significance

In South Africa, there are challenges of high landfill-type waste management from various sectors and this also includes the construction industry, which generates concrete waste (Abel, 2009). Hence projects are encouraged to have more environmentally friendly Waste Management Plans (WMP) (van Wyk, 2008). The industry is now shifting its focus from disposing of their wastes in landfills to the reduction, reuse and recycling of raw materials. WMPs are increasingly becoming an inherent part of the fabric of companies' operating models, especially for construction companies. Concrete continues to be a widely used construction material. However, the current status of management of concrete waste is difficult to assess due to the lack of readily accessible material on the topic. The available literature was extracted from published material focusing on managing C&D waste which includes concrete and cementitious material; however, there is still insufficient published material on management of concrete and cementitious waste material in the South African construction industry.

This study created awareness and also contributed effectively to the current practices and strategies for waste management of concrete and cementitious material in the construction sector of South Africa. This not only benefited the construction sector but it also contributed positively to the promotion of sustainability, as far as South Africa´s goals are concerned. Managing concrete and cementitious waste promotes a reduced exploitation of natural resources, reduced rates of landfill-type waste management and reduced Greenhouse gas (GHG) related transportation of waste materials (WBCSD, 2009).

Studies focusing on management of concrete and cementitious materials provide an opportunity to engage with other countries (both developed and developing) and relevant industries, consequently also exploring other options to improve current approaches of waste management. The engagement allowed availability of more and broader information in implementing sustainable waste management procedures for concrete and cementitious material, therefore contributing in moving towards a green economy through the country's targets[2]. This study also assisted in identifying critical aspects of managing waste in the construction sector taking into account past research.

[2] 34% deviation by 2020 and 42% by 2025 through NAMAs (see chapter 1, section 1.1)

In summary, the study assessed practises and strategies for waste management of concrete and cementitious materials in South Africa's construction sector. The intention was for the research to contribute towards attaining better and evolved approaches of managing concrete and cementitious waste in South Africa.

## 1.5. Aim and objectives

### 1.5.1. Aim

The aim of the study was to analyse, critically review and examine current practices and strategies for waste management of concrete and cement-based materials in the construction sector of South Africa.

### 1.5.2. Objectives

1. Assess the knowledge and understanding of practitioners (such as engineers, site managers, project managers, quantity surveyors and general workers) regarding C&D waste policies and legislations.
2. Assess the current implementation of strategies for waste (concrete and cementitious materials) management in South Africa.
3. Critically compare and contrast practices and strategies for waste management of concrete and cement-based materials in South Africa using selected case studies.
4. Compare and contrast South African strategies of managing waste (concrete and cement-based materials) with those from other countries (both developed and developing).
5. Provide recommendations for future studies, and for managing concrete and cementitious waste materials in South Africa. This will be through comparing existing models and looking at how they can be further developed.

## 1.6. Scope of the study

The approach of the study was in the form of qualitative research. The fundamental methods for this study were critical literature review, use of questionnaires and case studies.

The case studies and questionnaire were treated as primary data sources of the study and the published literature as a secondary source. Case studies were based on observations of practices used on site in managing concrete and cementitious materials waste, and the questionnaires were used for assessing the knowledge and perception of practitioners on waste management, its policies and legislation in South Africa. Case studies were conducted in five active construction sites with ten questionnaires distributed per site.

The intention was to select active project sites in South Africa, Gauteng Province. The selection of sites was based on their location, nature of project, accessibility, approval by management of the construction site and other relevant factors that could affect the study. The study was conducted within a time-frame of six months due to time constraints to allow enough time for analysing and interpreting the data.

### 1.7. Limitations

The limitations of the research are;

- Time - the Study was over a period of six to twelve months
- Location - the study was primarily based in South Africa, with case studies in Gauteng provinces.
- Size - only five active construction projects were used.

### 1.8. Organisation of the report

The research report will be divided into five chapters and they will be arranged as follows:

- Chapter 1: Introduction (current chapter) – background, define aim, objectives, limitations, research questions and also identify research scope.
- Chapter 2: Literature review – Review of the known and unknown literature within the scope of the study.
- Chapter 3: Methodology – define methodology of the research, collection of data and define data analysis procedure.
- Chapter 4: Results and discussion – present results of the research, analyse and interpret them.
- Chapter 5: Conclusions and recommendations– review the findings of the research, make conclusions and provide recommendations.

# CHAPTER 2: LITERATURE REVIEW

## 2.1. Introduction

The practice of construction and demolition waste being transported to landfill is reported to be a global problem rather than a country-specific problem and as highlighted before[3], South Africa is one of the countries faced with this challenge. Concrete is reported to be the second most consumed material after water and it is therefore essential, in the view of the researcher, to understand the behaviour of this material as well as its application to use it more efficiently (WBCSD, 2009). However, it is also important to gauge how users perceive the material when it is in excess, to understand if they see potential use-value in it or not. As a result, the goal of this study is to analyse, critically review and examine current practices and strategies for waste management of concrete and cement-based material in the construction sector of South Africa.

## 2.2. Sustainability and sustainable development in the construction sector

### 2.2.1. Definition of sustainability and sustainable development in construction

Sustainable development is a well-known phrase in the current era and possibly even one of the most misused terms (Utting, 2015). According to literature, there is no consensus on the definition of the term sustainability (Dempsey *et al.*, 2011). Based on research conducted, sustainable development does not seem to be a one-size-fits-all concept particularly given the rate in which the term continues to grow in use. The term is not easy to define due to the evolution of its meaning and scholars even argue that the definition should revert to its ´original´ characterisation, which emphasised more on "the well-being of future generations and in particular irreplaceable natural resources" (Kuhlman & Farrington, 2010). The argument lies on the basis that the evolution of its definition is deviating from the original meaning. As it stands, the definition has evolved such that one cannot attempt to interpret it without referring to the three 'components' of sustainable development; being social, economic and environmental (Hansmann, Mieg and Frischknecht, 2012). It is a matter of how each sector defines it and what it means to them.

[3] See chapter 1 section 1.1

It might be beneficial for each nation to define sustainable development for its own goals however it could also be beneficial to have a consensus on an international level regarding its definition, to enable countries to work towards the same goal and vision. Nonetheless, it is still a relevant concept to the world and different economic sectors including the construction sector.

For this study sustainable development is defined as "*Development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" (WCED, 1987). The definition was adopted for this study since it is arguably the "most frequently quoted" definition (Spangenberg, 2000) and also because the researcher understood it to be a better fit for the study compared to other definitions available from literature.

Construction projects aim to deliver the product that meets the desired quality specifications at minimal costs and within a given period. This is usually termed the triple constraint. These three deliverables (i.e. quality, cost, time) are fragile for any construction project and continuously trade-off among each other as they are less likely to be equally balanced. It is argued that "the triple-constraint emphasises on profit 'P' which is associated with the cost deliverable. The social and environmental aspects may be included as aspects of the quality of the result, but they are bound to get less attention" (Silvius and Schipper, 2010). Due to this argument of profit dominating the triple constraints, there is an emerging study where scholars suggest the incorporation of sustainability in project deliverables through project management (Silvius and Schipper, 2014, 2015; Olaso and Ramón, 2016). Waste management as a component of sustainable development does not form part of a project's deliverables, at least not directly. However, it is becoming an important component from planning to end life phase of a project. This is because it is close to impossible to complete a construction project without generating waste or excess material.

### 2.3. Construction and demolition waste

Similar to sustainable development, currently there is no worldwide agreement on the explicit meaning of C&D waste (Laquatra and Pierce, 2011). The general sense is that most definitions prioritise effects upon the ecological environment (Bourdeau, 1999). These differing views in defining C&D waste poses a challenge for scholars especially when trying to interlink different studies from one nation to another (Lu and Yuan, 2011). Yet they also promote the exchange of ideas between countries. It is however important that countries reach a common ground in defining sustainable construction (Du Plessis, 2007). Having a common ground on the definition could encourage better evolved and refined practice in moving forward since construction services still hold great value in society.

For this study, the definition of C&D waste is adapted from the National Environmental Management: Waste Bill of 2007 which defines it as *"Waste produced during the construction, alteration, repair or demolition of any structure, and includes rubble, earth, rock and wood displaced during that construction, alteration, repair or demolition"*.

### 2.3.1. Life cycle of a construction project

A construction project undergoes various phases from its inception to completion as shown in **Figure 2**.

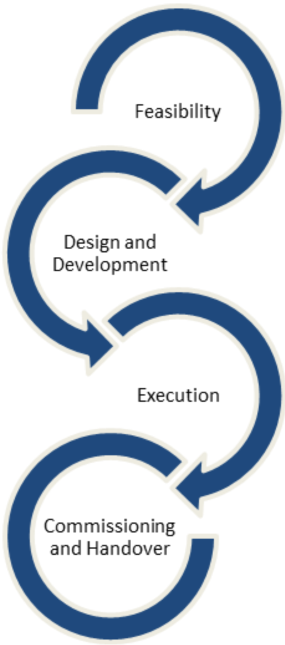


**Figure 2**: Construction Project Life Cycle (4 Phases); (Burke, 2010)

The project life cycle phases are further explained below, as per the study from (Chichester, 2012; Carstens, Richardson and Smith, 2013).

**Phase 1: Feasibility**

The feasibility phase intends to enable decision making on the option that best suits the brief. The phase starts with laying out the brief of the project and thereafter going through the existing variety of alternatives and lastly choosing the most applicable alternative. The process includes examining and developing all factors of the project to provide a comprehensive review of the alternatives available. A comprehensive review will ideally consider all elements that will affect the project from the design throughout to completion.

The processes involved in this phase can be summarised as follows:

- Identify site constraints and opportunities
- Select and appoint consultants to help complete the feasibility study
- Develop the project brief (Define objectives and constraints)
- Develop a preliminary project master programme
- Identify all options, appraise and select the preferred option
- Carry out funding investment and appraisal exercise
- Establish the project organisation and control mechanisms
- Identify the procurement strategy
- Complete a cost plan, cash flow plan and development budget
- Prepare a full business case
- Obtain approval to proceed

**Phase 2: Design and development**

The design and development phase intends to provide detailed information of the project´s specifications. The starting point for this phase is the design framework that was produced during the feasibility phase. It advances to detailed design and final design then to the assembling of the information.

The process in this phase has a frequent repetition nature and because of this trait, the level of details in the design strengthen further as the process evolves from the outline stage to the detailed stage and the final design stage, thus increasing the validities while decreasing assumptions in the project.

The design process should be controlled and programmed. It is essential:

- For the Designers to be aware of the cost limits within which to design at the outset of the project
- For the Project Manager to retain overall control of time and cost
- To be aware that design is a means to an end and not an end in itself

- That all relevant information is prepared promptly both for the needs of cost forecasting and appropriate cost planning of the construction process

**Phase 3: Execution**

The execution phase aims to build the physical project and hand over the deliverables to the client. This phase is commonly the most time-consuming, energy-consuming and resource-consuming among the other phases of the project life cycle.

Execution of a project includes:

- Project Design
- Change Management
- Project Scope Management
- Managing Project Performance
- Documentation

**Phase 4: Commissioning and handover**

The commissioning and handover phase, the last phase of the project life cycle, intends to demonstrate that the final product functions properly as per the design requirements and safely and soundly. The phase includes project completion, product testing, product inspection, and project acceptance. Where faults are recognised during the process, they are permitted to be modified before the final scheduled handover date.

2.3.2. Concrete and cementitious waste production in the life cycle of a construction project

Concrete and cementitious waste is initially generated during the execution phase of a project. During this phase, physical activities are performed such as building, demolishing and concrete mixing.

Though concrete and cementitious waste is generated during the execution phase (as mentioned above), large quantities of concrete and cementitious waste could also come from decommissioning stage of concrete structures. At this stage, the structures are at the end of their life cycle and when demolished, the waste generated mostly ends up on landfill. Therefore for this research, a construction project life cycle model as shown in **Figure 2** does not portray a full and substantial view for analysis, because it does not consider phases of usage, maintenance and end life of a structure i.e. decommissioning stage.

At the decommissioning stage concrete and cementitious waste can be generated when demolishing structures such as roads, pavements and houses. Presently there is inadequate literature published on this type of waste in South Africa. On a national scale, there is sufficient information on C&D waste in general but there is limited information specific to waste categories. It then creates an opportunity for further studies to be conducted in categorising waste according to their specific type; which is concrete and cementitious material in this case. Studies report that in the European Union (EU) approximately 30% (850 million tons) of total waste is purely from construction and demolition waste (Tosic, Marinkovic and Stojanovic, 2017). With such a large volume of waste, it is imperative to implement proper structures for dealing with the waste, to avoid resorting to landfill as a solution.

### 2.3.2. Life cycle of a concrete structure

For better understanding on the relationship between sustainable development and concrete and cementitious waste, a model was developed called the life cycle phases of a concrete structure as shown in **Figure 3**. (Muigai, Alexander and Moyo, 2013). This model stems from what is known as ´cradle to grave´ or ´cradle to cradle´ depending on preference. For this study, it will be called cradle to grave. The cradle to grave technique "necessitates identification of the products life cycle and the processes participating in it" (Munoz and Maria, 2013). The description of the product´s life cycle, in particular for products that have a long life span such as concrete infrastructure, includes assumptions and estimates for the following as highlighted by Munoz and Maria (2013):

- Functional service lifetime
- Use and maintenance scenarios
- Repair and replacement of components
- Major refurbishment or renovation scenarios for the building
- Demolition and recycling scenarios

The life cycle is classified into three phases being cradle to gate, cradle to grave and grave to cradle shown in **Figure 3** and the phases elaborated below.

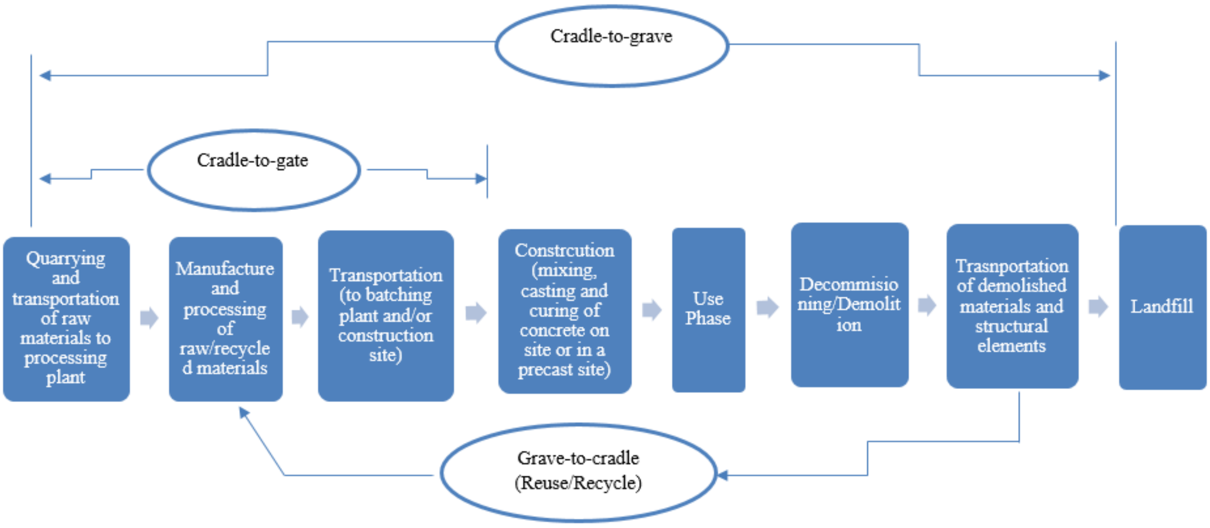


**Figure 3**: Life Cycle Phases of a concrete Structure (Muigai, Alexander and Moyo, 2013)

*2.3.2.1. Cradle to gate phase*

This phase covers the period from raw material extraction to the factory gate (ICCA, 2010). With concrete structures, this phase covers stages of extraction, manufacturing, and to up until transportation of the concrete to construction sites (Muigai, Alexander and Moyo, 2013).

*2.3.2.2. Cradle to grave phase*

The phase covers the period from raw material extraction through product use and disposal (ICCA, 2010). Regarding concrete structures, this phase covers stages on-site from mixing, transportation on-site, construction, up to the demolition of the structure (Muigai, Alexander and Moyo, 2013).

*2.3.2.3. Grave to cradle phase*

The phase covers the period from one defined point along the life cycle (e.g., where incoming raw materials cross the fence-line of a manufacturing site) to a second defined point further along the life cycle (e.g., where a finished product is delivered to an end-user) (ICCA, 2010). For concrete structures, this phase covers stages of recovering the material from demolition through recycling and reusing (Muigai, Alexander and Moyo, 2013).

The model in **Figure 3** is a bridge of the gap identified in construction project life cycle (4 Phases) shown in the **Figure 2** model. **Figure 3** shows the end life cycle of a project and it is necessary to understand a cycle that typical concrete structures goes through. Concerning this study most consideration will be given to the last two phases of the cycle being; gate-to-grave phase and the grave-to-cradle phase. According to the cycle shown in **Figure 3** once demolition of the structure occurs and waste is generated, the material will be transported either to landfill or back to the manufacturing/processing site for reusing and/or recycling. In South Africa most of this waste is transported to landfill i.e. the last phase of the cycle (Barnes, 2016). In addition to that, the country also faces challenges of illegal dumping (Abel, 2009). This is when unauthorised methods are used and "waste larger than litter is dumped in public areas or illegal landfills" (CleanUpAustralia, 2011). Due to lack of technology and process information in the country people then resort to landfilling.

The supply, processing and demand of concrete and cementitious material determine the economic viability such that the transportation and processing costs should remain less than the market value of the material (Barnes, 2016). It is anticipated that the grave-to-cradle phase has the potential to reduce landfill for concrete waste in South Africa (Muigai, Alexander and Moyo, 2013). For landfill of concrete and cementitious waste material to be reduced there would need to be strategies in place. To use waste concrete and cementitious material to its maximum potential, it is important to understand what achievements can be reached with this type of material.

The life cycle shown in **Figure 3** discourages the idea of the life of concrete ending on a landfill through disposal. It shifts the way concrete and cementitious material, and C&D waste in general, are treated in their life progression by the users. The model in **Figure 3** is supported by **Figure 4** which indicates how the general flow of material can be modified due to increasing need to move away from disposal of C&D waste where material could be recoverable.

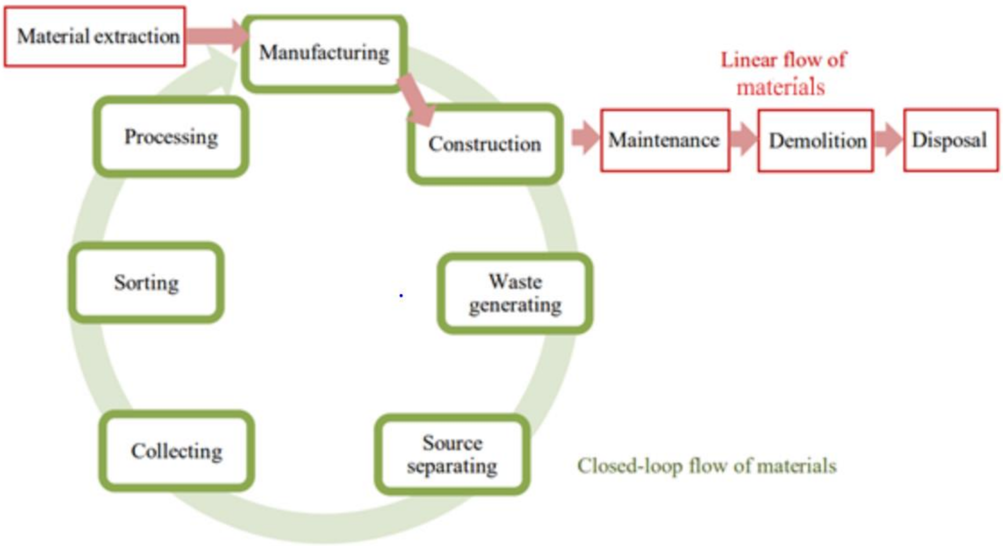


**Figure 4**: Linear and closed-loop model of C&D waste (Brennan et al., 2014)

**Figure 4** demonstrates two possible routes that material can go through. Firstly it shows the traditional route of material starting from material extraction until material disposal. This route is named linear flow of materials. This model rather advocates adoption of the alternative route which shows the route of the material starting from material extraction until processing, and back to manufacturing. This route is named closed-loop flow of materials. This model has an interrelation with the life cycle phases of a concrete structure in **Figure 3** in a manner that the flow of material is not linear. There is rather a cycle type of flow in both models that the material goes through to minimise resorting to landfill before exploring other available options for recoverable material.

## 2.4. Waste management strategies in South Africa

### 2.4.1. An overview

South Africa produced 107.8 million tonnes of waste in 2017 as reported by (DEA, 2018). This is not a significant difference from the 108 million tonnes of waste produced in 2011reported by (Godfrey, 2015). The per capita output of the waste generated decreased from 2.08 in 2011 to 1.89 in 2017. The reason of the reduction in the per capita output is not mentioned in reports and available literature. However, when looking at the legislative timeline (**Figure 7**), more policies were introduced between 2010 and 2017, and they also might have contributed to the reduction of the per capita output.

Though this is the case, when looking into C&D waste production it has decreased in the year 2017. See in **Figure 5** a comparison made of waste produced in 2011 and 2017.

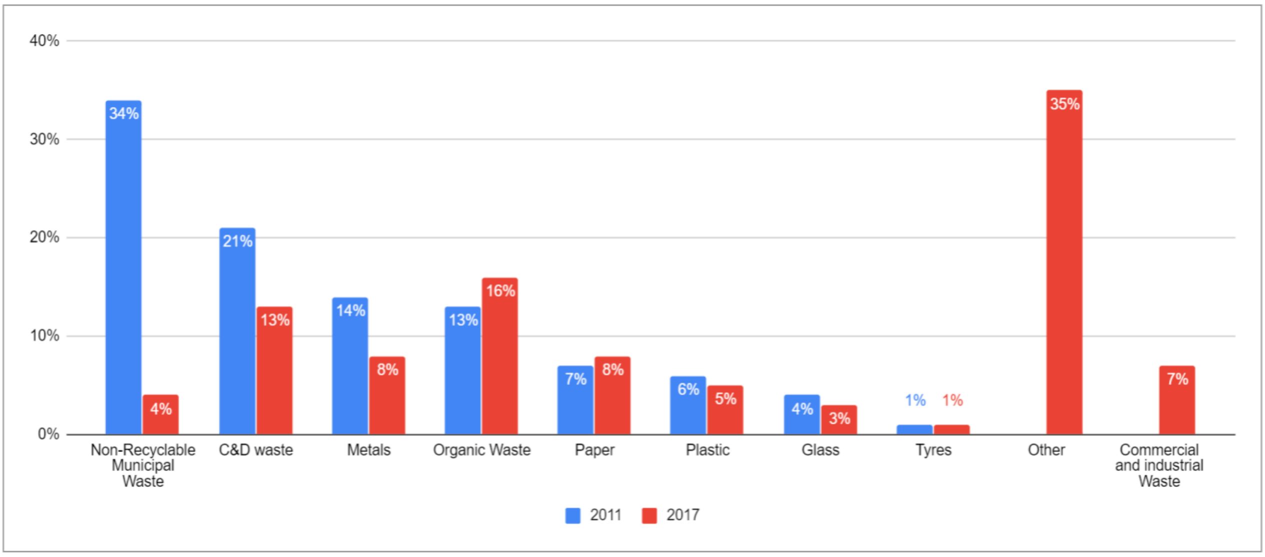


**Figure 5**: A comparison of waste breakdown between years 2011 and 2017. 2011 data from (Godfrey, 2015) and 2017 data from (DEA, 2018)

The comparison in **Figure 5** shows that in 2011 C&D waste was the second-highest waste producer at 21% after non-recyclable municipal waste whereas in 2017 it was the third-highest waste producer at 13% after other and organic waste. In 2017, the non-recyclable municipal waste had a drastic decrease from 34% to 4%. However, it should be noted that two ´new´ categories were added in the 2017 breakdown (other and commercial and industrial waste) and therefore this could have affected municipal waste category and possibly other categories too. At this stage, there is no literature that explains how the C&D sector achieved a decrease in waste production in 2017. Though this is the case, waste in SA is managed through strategies outlined in the State of Waste Report (SoWR).

In SA, management of waste is led by the National Waste Management Strategy (NWMS) which is a "legislative requirement of the National Environmental Management: Waste Act, 2008 (Act No. 59 of 2008), the ´Waste Act´. The purpose of the NWMS is to achieve the objects of the Waste Act. Organs of state and affected persons are obliged to give effect to the NWMS" (DEA, 2011).

The eight strategic goals around which the NWMS is structured are as follows (DEA, 2011):

**Goal 1: Promote waste minimisation, re-use, recycling and recovery of waste.**
*Focuses on implementing the waste management hierarchy, and with the ultimate aim of diverting waste from landfill.*

**Goal 2: Ensure the effective and efficient delivery of waste services.**
*Promotes access to at least a basic level of waste services for all and integrates the waste management hierarchy into waste services, including separation at source.*

**Goal 3: Grow the contribution of the waste sector to the green economy.**
*Emphasises the social and economic impact of waste management, and situates the waste strategy within the green economy approach.*

**Goal 4: Ensure that people are aware of the impact of waste on their health, wellbeing and the environment.**
*Seeks to involve communities and people as active participants in implementing a new approach to waste management.*

**Goal 5: Achieve integrated waste management planning.**
*Creates a mechanism for integrated, transparent and systematic planning of waste management activities at each level of government.*

**Goal 6: Ensure sound budgeting and financial management for waste services.**
*Provides mechanisms to establish a sustainable financial basis for providing waste services.*

**Goal 7: Provide measures to remediate contaminated land.**
*Addresses the massive backlog of public and privately owned contaminated land in South Africa.*

**Goal 8: Establish effective compliance with and enforcement of the Waste Act.**

*Ensures that everyone adheres to the regulatory requirements for waste management, and builds a culture of compliance.*

The SoWR states that the DEA plans to launch "dedicated mechanisms to co-ordinate the efforts of Waste Management Officers (WMOs)" (DEA, 2018). The idea is to establish waste councils at district, provincial and national level. **Figure 6** shows how this will be structured at a national level.

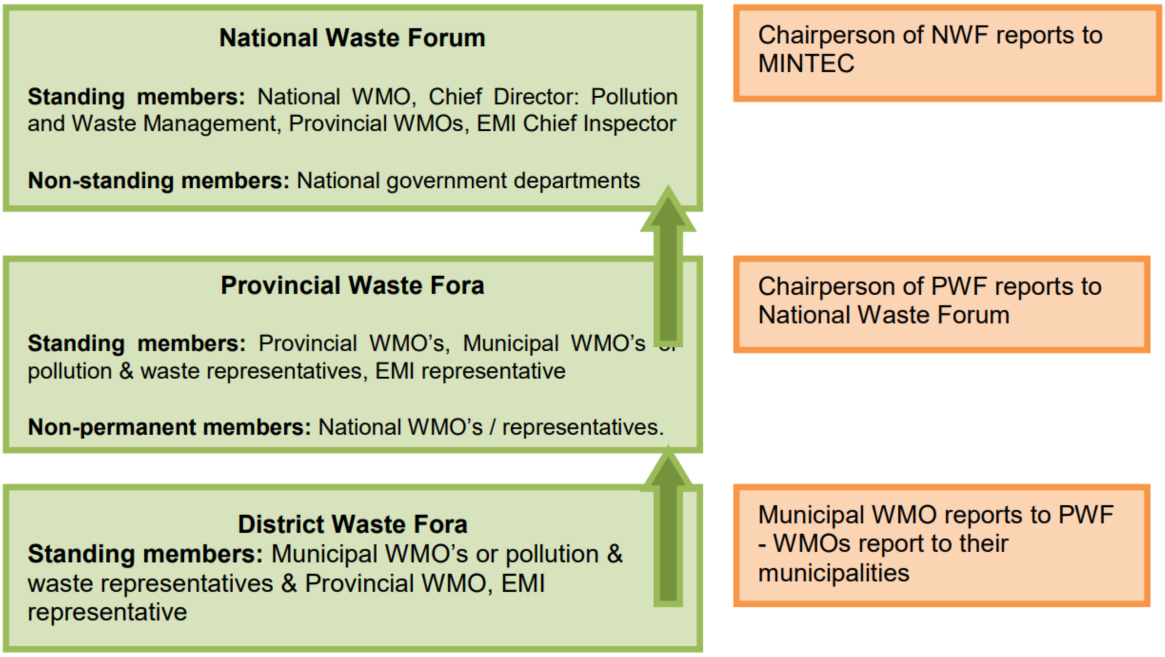


**Figure 6**: Coordination mechanisms for WMOs (DEA, 2018)

Since this is a new approach in SA waste management strategies, in the next SoWR it will be interesting to see how this mechanism would have contributed to the management of waste, and C&D waste in particular.

To report and keep record on waste production in South Africa, the DEA releases SoWR document that reports on waste in general and the document was developed through a legislative timeline shown in **Figure 7** (DEA, 2018).


**Figure 7**: Legislative timeline leading to the SoWR (DEA, 2018)

The NWMS is further navigated by the waste management hierarchy approach and this is because the waste management hierarchy "is the overall approach that informs waste management in South Africa" (DEA, 2011). **Figure 8** shows the waste management hierarchy adopted by SA.

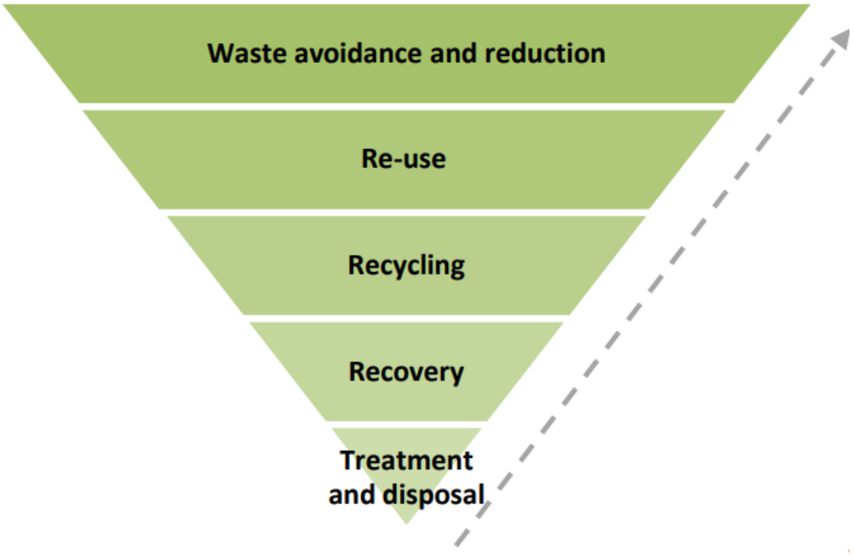


**Figure 8**: Waste management hierarchy (DEA, 2011)

The hierarchy is defined below.

1. Reduce

This principle is concerned with minimising the amount of material used by applying techniques that will require less amount of it. The technique aims to lessen waste quantities by avoiding its generation in the first place, through reduction of the quantities of primary resources needed initially.

2. Re-use

Sourcing waste material directly after use and using it again for a similar cause, as a secondary material. The technique encourages the use of secondary materials, therefore preserving primary materials where possible. It is referred to as grave-to-cradle phase in the lifecycle phases of a concrete structure.

An important note for this study is that concrete and cementitious waste cannot be restored to its original state for use. However, the recycled material can be used in the form of aggregates; termed recycled concrete aggregates (RCA) (Tosic, Marinkovic and Stojanovic, 2017).

3. Recycle

Reprocessing useful waste material, provided it cannot be reused. This method is least preferred compared to reuse because it still requires the use of energy for reprocessing. Even though it is preferred as a last resort, it is still useful since it also encourages the use of secondary materials. It is also referred to as grave-to-cradle phase in the lifecycle phases of a concrete structure.

4. Recovery

Recovery involves reclaiming particular components or materials or using the waste as a fuel.

5. Treatment and disposal

As a last resort, waste enters the lowest level of the hierarchy to be treated and/or disposed of, depending on the safest manner for its final disposal.

2.4.2. Raw material versus secondary material in South Africa

A study conducted reports that supply chain of virgin materials is observed to be longer than that of secondary materials (Barnes, 2016). The model in **Figure 9** below shows the difference between processing primary and secondary materials.

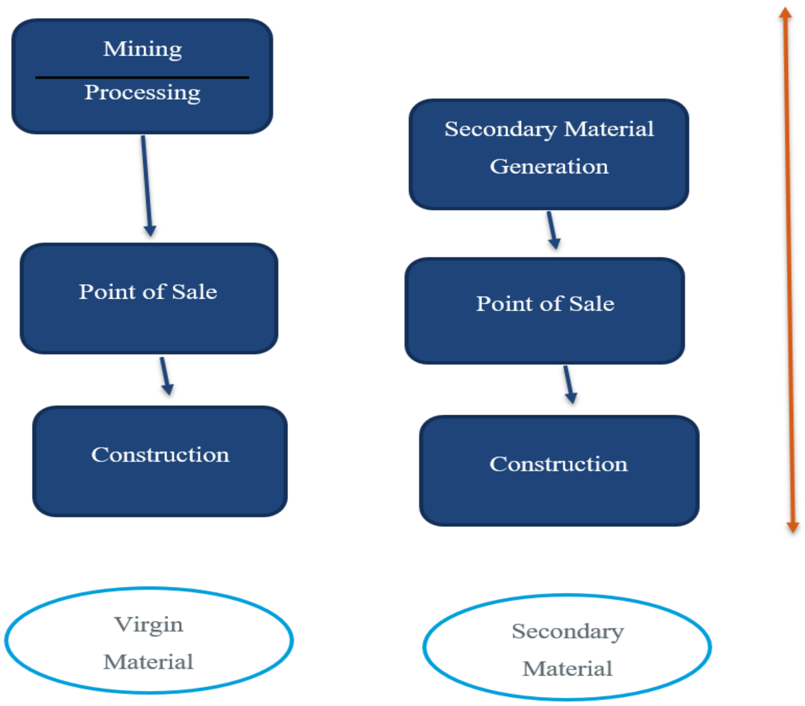


**Figure 9**: Supply Chain Benefits of Secondary Materials (Barnes, 2016)

**Table 1** outlines the myths and truths for recycling waste concrete and cementitious material (WBCSD, 2009).**Table 1**: Myths and truths for recycling concrete (WBCSD, 2009).

| **Item no.** | **Myths** | **Reality** |
|---|---|---|
| 1 | Concrete cannot be recycled | Although concrete is not broken down into its constituent parts, it can be recovered and crushed for reuse as aggregate (for use in ready-mix concrete or other applications) or it can be recycled through the cement manufacturing process in controlled amounts, either as an alternative raw material to produce clinker or as an additional component when grinding clinker, gypsum and other additives to cement. |
| 2 | Recycled concrete aggregate cannot be used for structural concrete | It is generally accepted that about 20% (or more) of aggregate content can be replaced by recycled concrete for structural applications. |
| 3 | Although some concrete can be recycled it is not possible to achieve high rates | Countries such as the Netherlands and Japan achieve near-complete recovery of waste concrete. |
| 4 | Concrete can be 100% made by recycling old concrete | Current technology means that recovered concrete can be used as aggregate in new concrete but (1) new cement is always needed and (2) in most applications only a portion of recycled aggregate content can be used (regulations often limit content as do physical properties, particularly for structural concrete) |
| 5 | Recycling concrete will reduce greenhouse gases and the carbon footprint | Most greenhouse gas emissions from concrete production occur during the production of cement. Less-significant savings may be made if transportation needs for aggregates can be reduced by recycling. |
| 6 | Recycling concrete into low-grade aggregate is down-cycling and is environmentally not the best solution | A full lifecycle assessment should be undertaken. Sometimes low-grade use is the most sustainable solution as it diverts other resources from the project and uses minimal energy in processing. That is not to say more refined uses might not also suit a situation. |
| 7 | Recycled aggregate is more expensive | This depends on local conditions (including transportation costs) |

For this study, recycled concrete can be used as either aggregate or blocks. The aggregate can be coarse, fine or as filler material, and the blocks can be in original or cut-down form. (WBCSD, 2009).

According to WBCSD (2009), there are various forms to recycle concrete such as from; “returned concrete that is fresh (wet) from ready-mix trucks, production waste at a pre-cast production facility, construction and demolition”. However, it is also argued that most of the waste is still produced through construction and demolition waste (WBCSD, 2009). To know how good the South African strategies are on an international standard, it would also be beneficial to look into other countries for comparison.An organisation called the builders’ rubble in the City of Cape Town make use of the recycling strategy to avail secondary materials for reuse in road construction, while at the same time also helping reduce landfill (Barnes, 2016). This is a good example of how the waste management hierarchy can be used in the South African construction industry, to address the issue of landfill. This shows that there are strategies in place. However, the country is still encountering large amounts of C&D waste disposed on land.

The waste management hierarchy principle has however been proven to be working in other parts of the world. China recycles concrete (Li, 2008) and uses it as a secondary material, e.g. as aggregate material. In Australia rubble (which includes concrete waste) is “among the most recycled waste material” (Kofoworola & Gheewala, 2008). The question, however, lies in what resources are available in South Africa (developing country) for recycling the concrete waste. That means the processing of primary materials will have to be compared with that of secondary material.

## 2.5. Waste management strategies in other countries

### 2.5.1. China

China is among the most populous countries and one of the biggest and leading economies in the world. With the rapid population and economic growth that the country experienced, it also saw a rise in waste production across its various sectors including in the construction sector. Researchers reported that the country also encounters the problem of illegal landfilling (Duran, Lenihan and O’Regan, 2006; Abel, 2009; Ichinose and Yamamoto, 2010). The country is improving their policies and one of their strategies is recycling concrete to minimise the amount of waste disposed on landfill. In 2002 China introduced a concept named the Circular Economy (CE) which was aimed at “addressing two critical national environmental problems – severe energy and resource constraints on the one hand; and excessive waste assimilation on the other hand” (Geng and Doberstein, 2008; Ampofo-Anti, 2015). This policy advocates the re-use of primary materials introduces the use of secondary materials and recommends landfill as the last resort in the process. It incorporates the "3Rs" (Reduce, Reuse, Recycle), and further emphasise on decreasing landfill. An illustration of this policy is well presented in the traditional waste hierarchy vs. new waste management paradigm model shown in **Figure 10**. The model illustrates how the policy affected the traditional waste hierarchy and thus converting it into the new waste management paradigm.

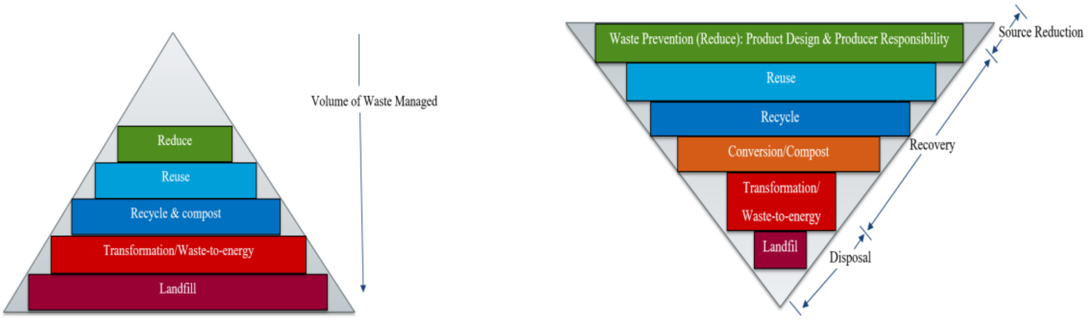


**Figure 10**: Traditional waste hierarchy vs New waste management paradigm (Ampofo-Anti, 2015)

When comparing the two models it is essential to note that on the traditional waste hierarchy landfill is the largest in volumes, while in the new waste management paradigm waste is prevented at the source, with landfill being the smallest in volume (Ampofo-Anti, 2015). Ideally, this is the mind-set that China seeks to adopt because it encourages less amounts of waste disposal. High levels of waste generation and landfill are similar challenges to those experienced in South Africa, and for that reason, the country is deemed a useful comparison for this study.

### 2.5.2. Australia

Australia is faced with accumulating C&D waste quantities even though waste recovery has been advancing and this is due to less progression of waste avoidance and minimisation (Li *et al.*, 2013). The Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) under the government of Australia reports that in 2009, the Australian environment ministers authorised the following National Waste Policy: *Less waste, more resources* (DSEWPaC, 2012). This policy intends "to avoid the generation of waste, reduce the amount of waste for disposal, manage waste as a resource and ensure that waste treatment, disposal, recovery and re-use is undertaken in a safe, scientific and environmentally-sound manner.” (DSEWPaC, 2012). The policy includes various strategies including one that is directed to C&D waste, i.e. Strategy 11, which states that ´*all governments continue to encourage best practice waste management and resource recovery for construction and demolition projects*´.

The essential tool for developing policies regarding full environmental, economic and social impacts of the waste policies is the waste hierarchy, **Figure 11** below.

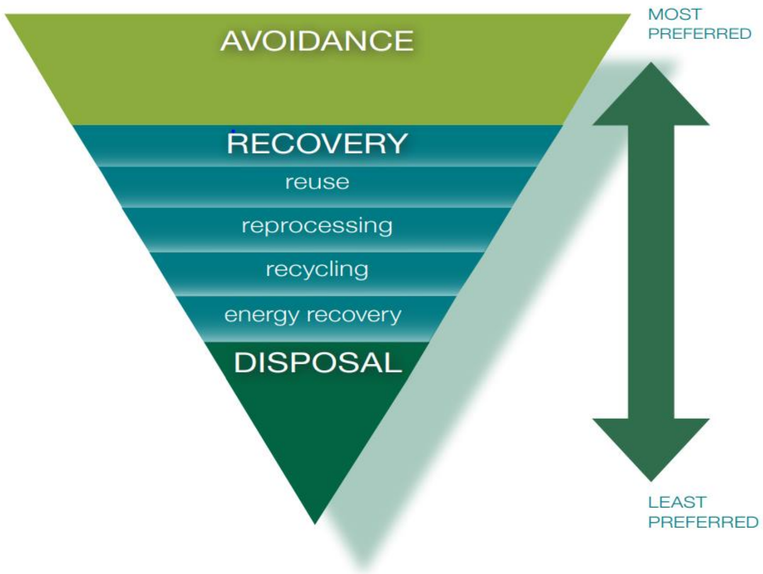


**Figure 11**: Waste hierarchy based on the WARR Act (WasteAuthority, 2013)

This tool is formulated by the Waste Authority in Australia using the results from the Waste Avoidance and Resource Recovery Act 2007 (Harris, 2017). The hierarchy is summarised by (WasteAuthority, 2013) from most preferred option to least preferred option as follows (WasteAuthority, 2013):

- Waste avoidance: prevention or reduction of waste generation, or the prevention or reduction of the environmental impacts (eg. toxicity) of waste generation.
- 
- Reuse: using a material or item again. Reuse is the most preferable form of recovery because it requires no (or minimal) resources and therefore has no (or minimal) environmental impact.

- Reprocessing: using an item or material that might otherwise become waste during the manufacturing or remanufacturing process. It may include actions both pre and post-consumption.
- Recycling: using recovered waste materials as substitutes for extracted raw materials. Recycling involves taking ‘waste’ materials or products and reconstituting those wastes into materials that have a market value.
- Energy recovery: process of converting waste products into some form of energy. It can include thermal treatment, which uses heat to release energy bound in waste or biological treatment which uses biological processes to convert biodegradable waste into a biogas which is rich in methane.
- Disposal: the discharge of waste into the environment, either into landfill or another disposal route. Disposal is the least preferred option in the waste hierarchy.

The options reuse, reprocessing, recycling, and energy recovery are collectively referred to as recovery which is explained as “several actions (including mechanical, thermal, biological, or chemical) that recover all or some of the materials that may otherwise be disposed” (WasteAuthority, 2013). This model echoes China´s new waste management paradigm model (see **Figure 10**).

In Australia, the Australian state and territory governments have to lead and control environmental issues, including waste management, instead of the national government (DSEWPaC, 2012). As a result waste management relies on the “regulatory framework” of the states and territories with commitment from different parties involved (DSEWPaC, 2012). Waste regulation spreads across the following jurisdictions; New South Wales, Victoria, Queensland, South Australia, Western Australia, Tasmania, Australian Capital Territory and Northern Territory. Below is **Table 2** with a summary of legislation that affects C&D waste and involves participation from different stakeholders across various jurisdictions.

**Table 2**: Legislation/Policy/Standards set by the State Government (WA) (Felmingham, 2015)

| **Legislation/Policy/Standards** | **How it Relates to C&D waste** |
|---|---|
| Environmental Protection Act 1986 | Makes policies and regulations for WA's waste management.<br>• Site clearing relating to dust and noise that impacts health.<br>• Transporting materials to/from site and stockpiling of wastes/recycled products on site. Ensure dust due to wind movement across unsealed areas and material movements.<br>• Poor site maintenance practices relating to pests, vermin and weeds that impact on local flora and fauna.<br>• Prevention of illegal dumping and issuing fines.<br>• Uncontrolled or poorly managed site run-off |
| Environmental Protection Regulation 1987 | Provides detail for the functioning of the Environmental Protection Act 1986. The regulation deals with prescribing the sorts of activities should be permitted as well as licensing and fees for applicable activities. |
| Environmental Protection Regulation (Controlled Waste) 2004 | Sets out a licensing and tracking system for transportation and disposal of waste such as asbestos and making it an offence not to comply. |
| Waste Avoidance and Resource Recovery Act 2007 | The key responsibilities of this Act are:<br>• The development of long term waste management strategy for WA.<br>• To improve waste services.<br>• To avoid waste generation.<br>• To set targets for resource recovery |
| Waste Avoidance and Resource Recovery Levy Act 2007 | This Act prescribes the levy that is payable in respect to waste received at disposal premises. The levy revenue is used to fund waste management initiatives. |
| Waste Avoidance and Resource Recovery Levy Regulations 2008 Waste Avoidance and Resource Levy Regulations Administration Policy 2009 | Outlines the levy requirements for the disposal of waste to landfill.<br>This policy relates to the WARR Act 2007, WARR Reg. 2008 and WARR Levy Reg. 2008 and provides a summary of the procedures and requirements for the assessment and calculation of the landfill levy on all waste received by licensed landfills in WA. |

| | |
|---|---|
| Draft Waste Strategy for Western Australia 2010 | Recommends government agencies and government-owned agencies to take 50% of the current C&D waste stream for use as raw material. Strategies and targets set:<br>• By 2016 C&D waste recovery rate of 50% |
| Extended Producer Responsibility Policy Statement | To ensure implementation of extended producer responsibility programs to problem wastes (C&D waste) as a priority for product stewardship schemes. |
| Main Roads Western Australia Specification 501 – Pavements | Allows the use of recycled concrete road base materials as a sub-base or base course in road construction. |
| Main Roads Western Australia Specification 201 – Quality Systems | Implementing a third-party certified management system or plan, for example, an AS/NZS ISO system. |
| Reducing Construction and Demolition Waste going to Landfill in WA – Draft discussion paper Nov 2010 | To replace a proportion of virgin material used in road base products with recycled materials. |

A construction and demolition waste status report by DSEWPaC recorded that Australia produced 19.0 million tonnes of C&D waste in 2008-2009 with 8.5 million tonnes dumped on landfill and 10.5 million tonnes recycled (HCEC&SRC, 2011). C&D accounts for approximately 20-30 per cent of the total waste dumped in landfills (Harris, 2017). South Africa in 2011 produced approximately 23 million tonnes[4] of C&D waste with no available record of how much of this waste could have ended in landfill. This is at least 21 per cent more to the waste produced by Australia in 2009.

A study conducted in Western Australia, Perth, reported that "the main components of waste produced are sand from earthworks (71.90%), concrete (23.86%) and bricks (3.31%)" (Felmingham, 2015). In this region concrete is the second highest waste producer in the C&D waste category. In South Africa, there is limited literature regarding the amount that concrete and cementitious waste material contributes towards the C&D waste.

### 2.5.3. Germany

Germany experiences economic growth and is identified as one of the countries with utmost waste recycling levels in the world (Li *et al.*, 2013).

[4] 21 per cent of 108 million tonnes. See Figure 5

Germany´s Waste Regulations as reported by Deloitte (2012) are:

**European laws**: *Waste disposal is governed by a number of European regulations and directives, whereby the former automatically apply to each of the member states, while the latter must be separately transposed into national law by each member state. The basis of this legal framework is the Waste Framework Directive (2008/98/EC), which defines the main waste-related terms, lays down a five-step waste hierarchy, and contains key provisions for German waste disposal law*.

**German Federal law**: *Germany's first uniform national waste disposal act, the Abfallbeseitigungsgesetz (AbfG), was adopted in 1972. The Circular Economy Act (KrWG), which is currently Germany's main waste disposal statute (and the successor to the KrW-/AbfG act), incorporates the main structural elements of the Kreislaufwirtschafts- und Abfallgesetz (KrW-/AbfG). Disposal of specific types of product waste (end-of-life vehicles, used batteries and end-of-life electronic and electrical devices) is governed by the ELV regulation (AltfahrzeugV), Batteriegesetz (BatterieG) and Elektro- und Elektronikgerätegesetz (ElektroG).*

**State law of Bundesländer**: *The Circular Economy Act (KrWG) is further differentiated by the Circular Economy Acts of the Bundesländer. However, due to the fact that, under the German Constitution, the federal government is charged with regulating waste disposal related matters (Article 74(1)(24)), the regional states only have jurisdiction over those aspects of waste disposal that are not already regulated by federal law. Hence, legal prescriptions in the state's law tend to address implementation related matters such as the following: determining which entities are subject to waste disposal obligations; the authorizing bodies for waste disposal matters; and municipal waste disposal ordinances*.

**Municipal waste disposal law**: *The collection and recovery of household waste at the municipal level are governed by municipal ordinances concerning matters such as usage and integration into the public system, as well as municipal garbage collection charges*.

**The Circular Economy Act (KrWG)**: *Germany's Circular Economy Act (KrWG) entered into force on 1 June 2012. The KrWG, which was enacted as Article 1 of the law titled "Gesetz Zur Neuordnung des Kreislaufwirtschafts- und Abfallrechts", supersedes the law titled*

*Kreislaufwirtschafts- und Abfallgesetz (KrW-/AbfG) and transposes Directive 2008/98/EC into German law. The Circular Economy Act (KrWG) is intended to tighten resource, climate and environmental protection regulations (see Article 1 of the Act).*

**Other regulations**: *The Circular Economy Act (KrWG) is supplemented and fleshed out by a number of other regulations such as the Abfallverzeichnis-Verordnung (AVV) regulation which lists the types of waste that are classified as hazardous, and those that are classified as non-hazardous. Hence, this regulation fleshes out the monitoring provisions of Article 47 ff. of the Circular Economy Act (KrWG).*

In Germany it is the duty of the national government, the Federal States and local authorities to lead and control waste management (Cave, 2017). Therefore the management of C&D waste involves inputs from different parties and not a single point of organisation. The responsibilities at each level are defined as follows:

- The National Ministry of environment: “sets priorities, drafts national legislation, oversees any strategic planning and information, and defines requirements for waste facilities” (Cave, 2017)
- Federal States: “Adopt their own waste management act in line with national legislation giving more perspective on approaches and rules for waste management and disposal. Waste management plans are also produced at the regional level by Federal States” (Christian Fischer, Emmanuel Gentil, Morten Ryberg, 2013)
- Local authorities (districts and town): responsible for household waste under the Recycling Management and Waste Act. This includes collecting, transporting waste, measures to promote waste prevention and recovery, and the construction and operation of waste disposal facilities.

The essential guide for developing legislation regarding waste management in Germany is the Waste Management Act 2012 which explains the waste hierarchy as a core tool (Cave, 2017). Cave (2017) explains the hierarchy arrangement to be in the order shown in **Figure 12**.

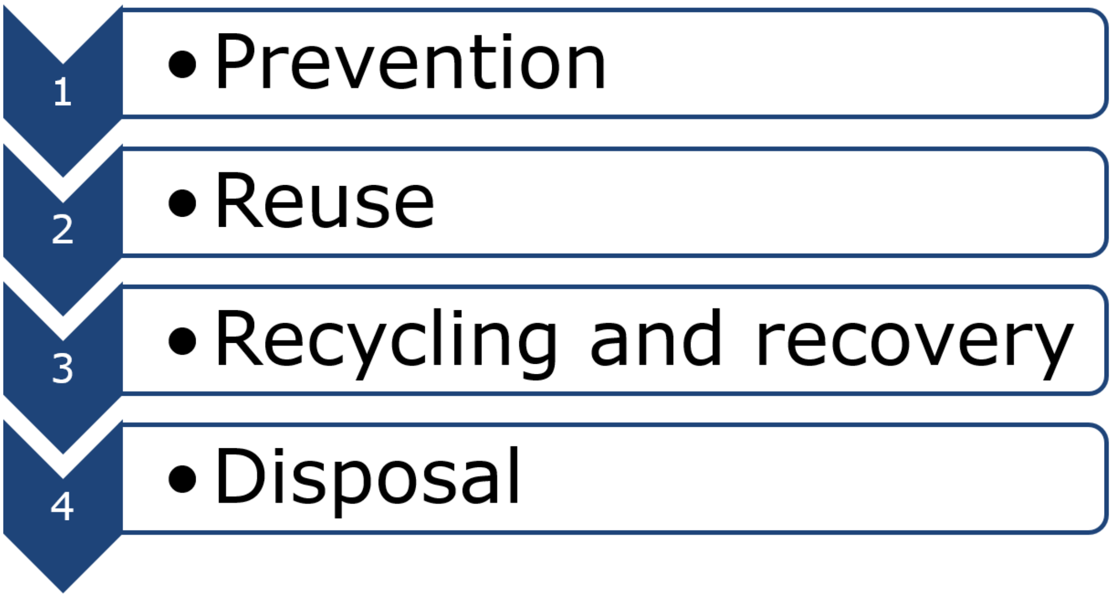


**Figure 12**: Waste management hierarchy

In summary, this hierarchy shows that Germany´s intention is "to minimise waste generation and maximise recycling while ensuring that any leftover waste is disposed of appropriately" (Cave, 2017). According to Germany´s Federal Statistical Office 2017, C&D generated 209.0 million tonnes of waste in 2015; while the recycling rate for C&D waste is measured to be at almost 90 per cent (Federal Ministry for the Environment, Nature, 2018). **Figure 13** demonstrates how the country´s C&D waste in 2015 was managed.

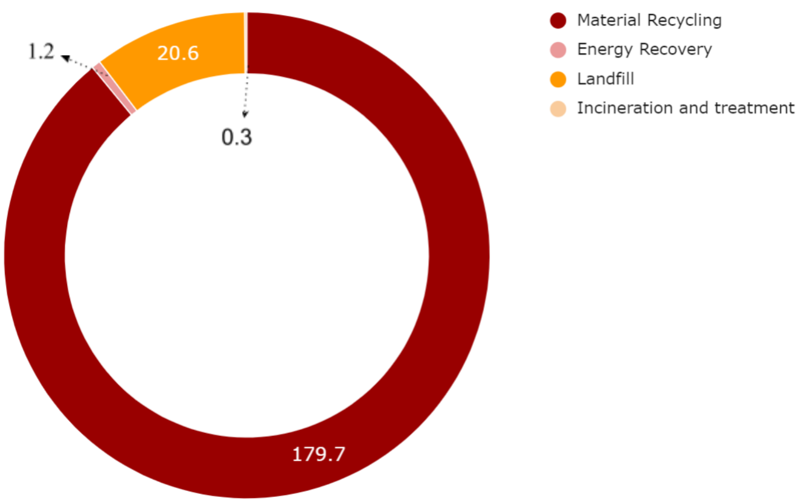


**Figure 13**: C&D waste 2015 (in million tonnes) by Federal Statistical Office,2017 (Federal Ministry for the Environment, Nature, 2018)

The C&D waste breakdown shown in **Figure 13** breaks down a total of 201.8 million tonnes produced versus the generated 209.0 million tonnes reported. The figure shows that Germany managed to recover 180.9 million tonnes of waste from material recycling and energy recovery, then disposed 20.9 million tonnes of waste from landfill and incineration & treatment (Federal Ministry for the Environment, Nature, 2018). According to Li *et al.* (2013) demolition work was seen to be producing more waste compared to new construction activities.

### 2.5.4. Kenya

In Kenya, the construction industry produces approximately 40% of solid waste which end up on dumping sites and in this waste, at least 70% of the material could be recovered instead of going to landfill (Wanja, 2016). Kenya drafted a vision 2030 report which includes a project for solid waste management initiative. The project aims to "call for relocation of the Dandora dumpsite and the development of solid waste management systems in five (5) leading municipalities and in the economic zones planned under vision 2030" (NEMA, 2015).

Below is Kenya´s Legal Framework applicable to Solid Waste Management and C&D waste, in particular (NEMA, 2015).

**Part 2 of the fourth Schedule Constitution of Kenya**: *the County Governments shall be responsible for; refuse removal, refuse dumps and solid waste disposal.*

**Environmental Management and Coordination (Waste Management) Regulations of 2006**:

*In the Responsibility of the Generator, Regulation 2 states that – ―Any person whose activities generate waste shall collect, segregate and dispose or cause to be disposed off such waste in the manner provided for under these Regulations.‖ Regulation 5 on the Segregation of waste by a generator states that – ―(1) Any person whose activities generate waste, shall segregate such waste by separating hazardous waste from non-hazardous waste and shall dispose of such wastes in such facility as is provided for by the relevant Local Authority.*

**The County Governments Act, 2012**

*Section 120, Tariffs and pricing of public services, subsection (3) A tariff policy adopted under subsection (1) shall reflect following guidelines — part (h) promotion of the economic, efficient,* *effective and sustainable use of resources, the recycling of waste, and other appropriate environmental objectives*

**The Environmental (Impact Assessment and Audit) Regulations, 2003**

*This regulation defines "waste" includes any matter prescribed to waste and any matter whether liquid, solid, gaseous or radioactive, which is discharged, emitted or deposited in the environment in such volume composition or manner likely to cause an alteration of the environment.*

**Part II - The Project Report,**

*7. (1) A proponent shall prepare a project report stating – (e) The materials to be used, products and by-products, including waste to be generated by the project and the methods of their disposal. (f) The products, by-products and waste generated project.*

**Part IV - The Environmental Impact Assessment Study Report, 18.**

*(1)A proponent shall submit to the Authority, an environmental contents of impact assessment study report incorporating but not limited to the environmental following information - (f) the products, by-products and waste generated project;*

**Part V - Environmental Audit and Monitoring 36,**

*(2) an environmental audit report compiled under these Regulations shall contain - (b) an indication of the various materials, including non-manufactured materials, the final products, and by-products, and waste generated.*

According to (NEMA, 2015) it is essential to implement integrated solid waste management as a principle with the main tool for this being the solid and integrated waste management hierarchy. The hierarchy is elaborated in **Figure 15**, following the layout of the traditional waste hierarchy in **Figure 14**.

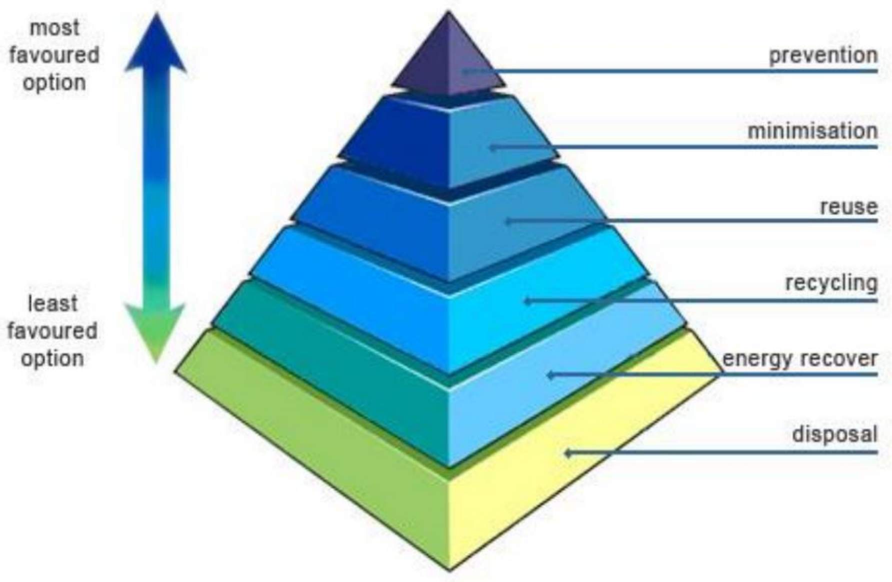


**Figure 14**: The solid waste management hierarchy (NEMA, 2015)

The solid waste management hierarchy has been in place in managing C&D waste though now this model is being transformed to the integrated waste management hierarchy, **Figure 15**.

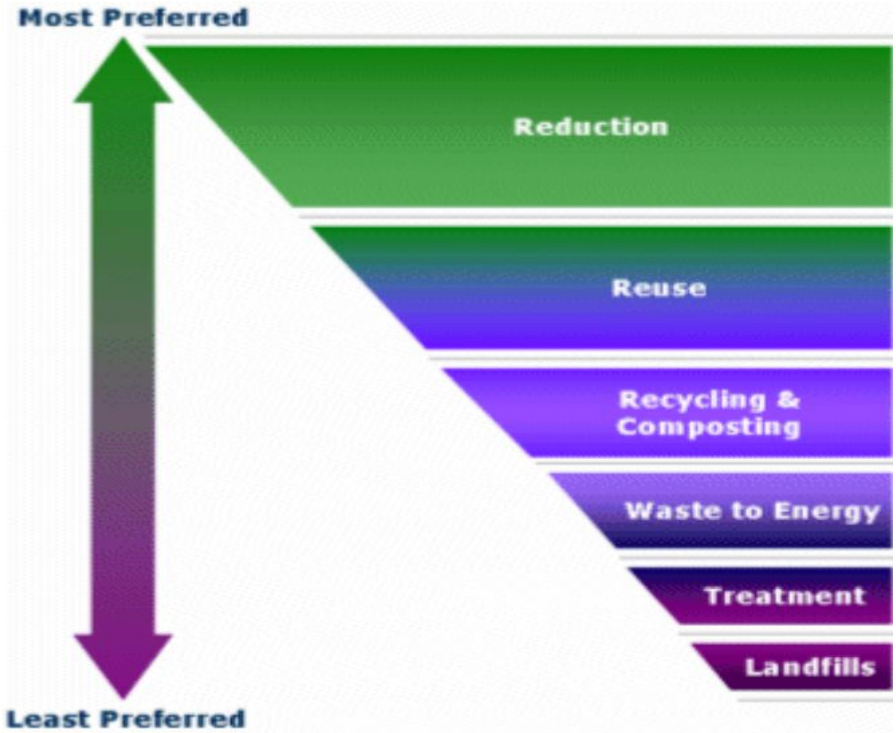


**Figure 15**: Integrated waste management hierarchy (NEMA, 2015)

Integrated waste management hierarchy is further explained by (NEMA, 2015) as follows:

- Reduction: Cleaner production, sustainable consumption and prevention
- Reuse: Reusing waste in its current form
- Recycling and composting: Processing waste to recover commercially valuable products
- Waste to energy: Recovering energy before final disposal of waste
- Treatment: Treatment to reduce volume (compaction, chemical treatment etc.)
- Landfill: Safe disposal of waste to landfills

A study was conducted to examine the "recycling of concrete waste in construction and demolition activities as an integrated solid waste management technique" in Kenya´s construction industry, and the results showed that "contractors do not recycle concrete waste." (Wanja, 2016). Waste material end up disposed on landfill in the dumping sites of Nairobi county (Wanja, 2016; Mbote, 2018). The study by Wanja (2016) was also a way to assess contribution levels by the Kenyan construction industry towards Kenya´s vision 2030 and based on the outcome, there is more to be done by the industry where the management of C&D waste, and for concrete, in particular, is concerned. Given that the construction industry make up at least 5% of Kenya´s GDP (Onyancha, B. M., & Kimutai, 2018). Therefore it is essential to understand how the sector will respond towards vision 2030.

A summary of the results by (Wanja, 2016)´s study states that:

- Contractors are not aware that concrete waste can be processed and incorporated back into construction in new projects. This point aligns with the observation outlined in item 1 of **Table 1**[5].
- Contractors claim that they are not confident about processed concrete waste for re-use because they do not think that it has reached the strength requirements of virgin concrete. This point aligns with the observation outlined in item 6 of **Table 1**[6].
- Virgin concrete is seen to be cheaper compared to recycling old concrete. This point aligns with the observation outlined in item 7 of **Table 1**[7].

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[5] Item 1 in Table 1 under Myth column.

[6] Item 6 in Table 1 under Myth column.

[7] Item 7 in Table 1 under Myth column.

- Contractors think the government is not intervening as much as it should regarding concrete recycling to assist them achieve the vision 2030.

The results further show that for “those who reuse and recycle concrete waste, only 25% sort out the waste before reusing while 75% do not sort out the concrete. From the whole sample population, none of the contractors process the concrete waste to add value to it to be recycled” (Wanja, 2016). Given these findings, they reiterate the arguments presented by Mbote, Kimtai and Makworo (2016) and Ayuya (2012) that reducing waste in the construction process is limited in Nairobi, Kenya.

According to (NEMA, 2015) the challenges Kenya faces with waste management include:

- Lack of awareness and knowledge
- Lack of positive political influence and lack of goodwill
- Disposal sites: Availability, siting and management
- Funding
- Lack of waste segregation
- Limited technical competencies
- Slow adoption of modern technological options

### 2.6. Chapter Summary

This chapter outlined the literature associated with C&D waste, as well and concrete waste. It looked into South Africa and four other countries (i.e. China, Australia, Germany, and Kenya) ways of managing solid waste and C&D waste in particular. What all the countries have in common with South Africa in managing C&D waste is that the waste hierarchy is the central tool for developing waste management strategies. It is also observed the waste hierarchy model is evolving from the traditional waste management hierarchy to the integrated hierarchy waste management.

# CHAPTER 3: METHODOLOGY

## 3.1. Introduction

Given that concrete and cementitious materials are widely used construction material in South Africa, the use of such material should be studied for better use and management. Currently, there is limited available information on the management of excess concrete and cementitious material in the construction sector of South Africa. This chapter outlines the methodology used in the research regarding the current practices and strategies for waste management of concrete and cement-based materials in the construction sector of South Africa. The methodology is outlined through demonstrating the research design, target population, design of the questionnaire, data collection and data analysis methods that were put into place during the study.

## 3.2. Research Design

In selecting the methodology for this study the researcher took into account the qualitative and quantitative options. These two methods have differences in conceptual and methodological aspects and they are shown **Table 3** below.

**Table 3:** Summary of Qualitative and Quantitative Methods (Minchiello et al., 1990)

| | **Qualitative** | **Quantitative** |
|---|---|---|
| Conceptual | Concerned with understanding human behaviour from the informant´s perspective.<br>Assumes a dynamic and negotiated reality. | Concerned with discovering facts about social phenomena.<br>Assumes a fixed and measurable reality. |
| Methodological | Data collected through participant observation and interviews.<br>Data analysed by themes from descriptions by informants.<br>Data reported in the language of the informant | Data collected through measuring objects.<br>Data analysed through numerical comparisons and statistical inferences.<br>Data reported through statistical analysis |

The study was conducted using the qualitative method. This method selection was guided by the aim[8] and objectives[9] of the study, having considered the comparisons between qualitative and quantitative methods shown in **Table 3**. The qualitative method was a better match to the aim of the study because the topic is not widely published in South Africa, allowing tapping into a new research field for future studies. According to (Sinaga, 2014), the qualitative method allows the researcher to "identify new and untouched phenomena; provide a deeper understanding of mechanisms; provide verbal information that may sometimes be converted to numerical form; reveal information that would not be identified through pre-determined survey questions". However the method can limit the researcher in providing results that are "general to the population, easily applied in statistical methods, easily assessed in relations between characteristics" (Sinaga, 2014).

## 3.3. Target Population: stakeholders in the construction sector

### 3.3.1. Sampling and sample population

Sampling was an important characteristic for this study as the respondents played a vital role in the research. In selecting participants, the researcher took into account the two main sampling techniques, i.e. probability sampling and non-probability sampling. The two techniques are summarised in **Table 4**.

The sampling procedure that was used is non-probability sampling and the sub-category that was applied was purposive sampling. Non-probability sampling is a form of sampling that is characterised by convenience. The procedure includes selecting a sample based on availability, convenience, or representation of specific characteristics the researcher is interested in; and purposive sampling is when the researcher ideally chooses the participants as per their judgement but keeping in mind the purpose of the study (Showkat & Parveen, 2017). The target population of this study was people working in construction sites, including but not limited to; engineers, site managers, project managers, quantity surveyors and general workers. This population was approached physically by the researcher during site visits in no particular order.

[8] See chapter 1 section 1.4.1 for the aim of the study

[9] See chapter 1 section 1.4.2 for objectives of the study

**Table 4:** Forms of Construction and demolition waste (Showkat & Parveen, 2017)

| | **Probability Sampling** | **Non-probability sampling** |
|---|---|---|
| General condition | Each sample has an equal probability of being chosen | Uses non-randomised methods to select the sample. |
| Knowledge of the sample | Each element of the population has a known non-zero probability of selection | Uses judgement, convenience and access to the sample |
| Application | More expensive, complicated and not easy to apply compared to non-probability sampling | Less expensive, less complicated, and easier to apply |
| Results | Gives probability that the sample is a representative of a population.<br>Generates high validity and generalization of a particular phenomena | Lacks generalizing of the sample to an entire population<br><br>Generates valuable insight on an existing phenomena, or developing a new one |
| Methods of sampling in each technique (sub-category) | Simple Random Sampling<br>Stratified Random Sampling<br>Systematic Random Sampling<br>Cluster Sampling<br>Multi-stage Systematic Sampling | Convenience Sampling<br>Purposive Sampling<br>Quota Sampling<br>Snowball Sampling |

### 3.4. Setting and instruments of the study

The study was conducted in Gauteng province, South Africa in June 2019. The aim was to visit five construction sites being small, medium and large categories. The researcher followed projects sizing guide as explained by the Tasmanian Government (2008) and Wilson (2014) shown in **Table 5**.

Out of the five construction sites visited one is under the small category, two are under the medium category, one is medium to large category and one is under the large category, as per **Table 5**. During the site visits, ten questionnaires were distributed to potential respondents on each construction site. The questionnaires were in hard copy form and the distribution was through hand delivery. In total, 50 hard copy questionnaires were distributed during the site visits. The goal was to achieve a 50% response rate from the distributed questionnaires.

The setting selected is deemed favourable for the study because it allowed the researcher to collect raw data from the site through observations of the processes being practised. And also, it allowed the researcher to engage with the workers on site through distributing the questionnaire survey and informal oral interviews to get a better understanding of their thoughts regarding the research topic. This provided a better understanding for the researcher when interpreting and analysing the data collected and therefore allowed the researcher to conclude the study conducted and also provide recommendations therefore.

**Table 5:** Factors determining project size (Wilson, 2014)

| | **Small** | **Medium** | **Large** |
|---|---|---|---|
| **Size of Project Team (FTE)**[10] | 1 – 2 | 2 – 5 | 6+ |
| **Completion Time** | < 6 months | 6 – 12 months | >12 months |
| **Timeframe** | Flexible Schedule | Minor variations acceptable | Deadline is fixed |
| **Complexity** | Easily understood problem, solution readily achievable | Either difficult to understand problem or solution unclear or difficult to achieve | Both problem and solution difficult to define or understand and solution difficult to achieve |
| **Strategic Importance** | Internal interest only | Some direct impact to a low priority initiative | Affects core University service delivery and/or directly relates to key initiatives in strategic plan |
| **Reputation Importance** | No reputation implications | Some reputation implications | Major reputation implications |
| **Total Cost** | <US $ 25k i.e.<br><br><R300k rounded off @<br>USD-ZAR 13.2471, 2018 average rate (Nebank, 2019) | USD $ 25k - $ 200k i.e.<br><br>R300k – R3 M rounded off @<br>USD-ZAR 13.2471, 2018 average rate (Nebank, 2019) | >US $ 200k i.e.<br><br>>R3 M rounded off @<br>USD-ZAR 13.2471, 2018 average rate (Nebank, 2019) |
| **Level of Change** | Impacts single area | Impacts number of areas | Impacts University |
| **Dependencies and Interrelated Projects** | No major dependencies | Some major low-risk dependencies | Major, high-risk dependencies |

## 3.5. Design of research questionnaire

3.5.1. Research ethics and ethics clearance

Before starting with the site visits to collect data, due process concerning research ethical requirements as stipulated by the University was followed through ethical clearances and obtaining request letter (i.e. additional support from the supervisor of the study) to submit to companies. The ethics clearance certificate is included in the appendix.

[10] FTE = Full Time Equivalent.

In the questionnaire the following ethical considerations were applied:

- Participant´s identity was kept anonymous.
- Participants were allowed to withdraw from the study at any point.
- Data submitted for the study was kept confidential and was not changed to suit the expectations of the researcher.
- Data submitted was secured by the researcher for the study and was not revealed to the public.

### 3.6. Data collection

The study commenced by approaching potential projects sites and requesting for approval to undertake the study. This was through sending emails and making telephone calls. However, due to time constraints and the lengthy procedures involved with telephones and emails, the researcher opted for approaching the companies´ Head offices in person, which resulted in quicker responses. This saved time of waiting for replies, and also cleared uncertainty quicker.

After access was granted from the Head offices for five construction sites, the researcher then contacted site managers and organised dates to conduct the visits. The researcher spent on average at least four hours per site. This involved attending Health Safety & Environment (HSE) inductions before conducting the study on site. During the study, practitioners on site were invited to partake in the study by completing the questionnaires distributed. All observations were recorded in the form of written notes and by taking images.

The questionnaires were collected on the same day of the site visit and analysed. The participants were allowed to get the results of the study upon their request after completion of the study. More information was also obtained from conducting a comprehensive and critical literature review concurrently, to gain a better understanding of the research topic.

Challenges encountered during the site visits include time restrictions, amount of pictures to take, and restrictions on whom to interview on the sites.

### 3.7 Data analysis methods

Analysis of the data began after site visits and continued to the end of the study. All data collected through questionnaires was kept in the form of soft copy files (cloud storage) and hard copy.

Data analysis was through the presentation of tables, graphs, standard coding systems. The method used in coding the data is an inductive approach; i.e. develop classy groups to code off from the data. This method was chosen because the intention was to illustrate the practitioners' view especially because the research topic is not well established and enabled the researcher to interpret and draw conclusions.

The suggested methodology as shown in **Figure 16**, provided valid information needed to analyse the management of C&D waste and therefore answering the main question of the study. In chapter 4 the data analysis will be shown in detail, including the results.

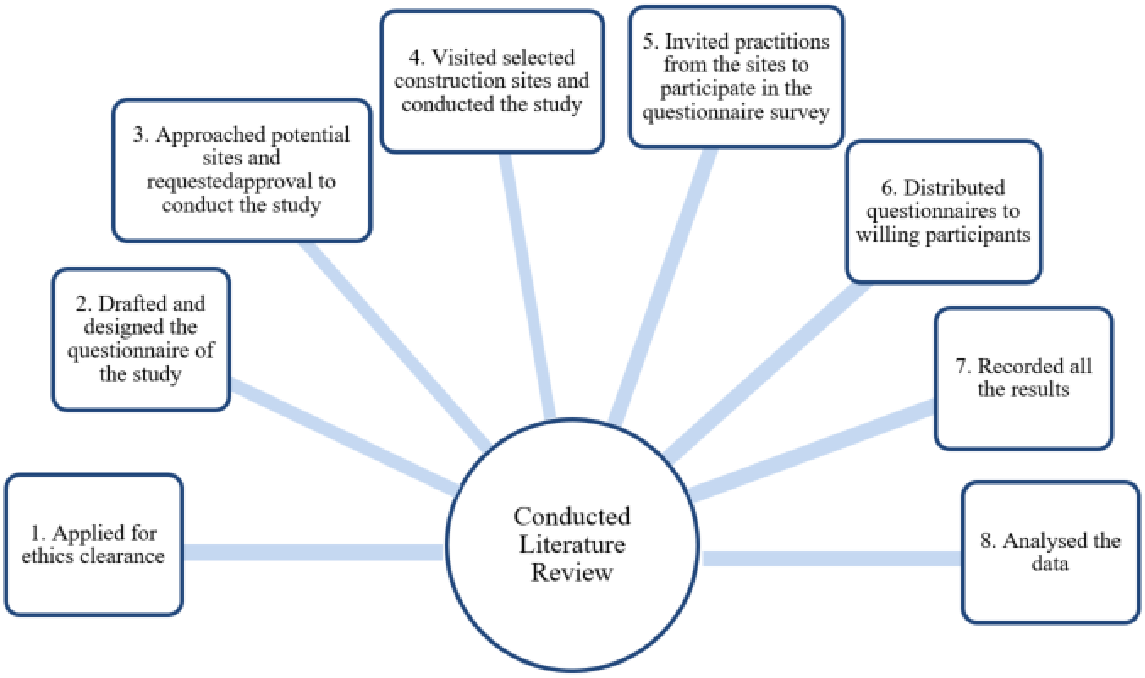


**Figure 16**: Schematic overview of the study

# CHAPTER 4: RESULTS AND DISCUSSION

## 4.1. Introduction

The researcher visited five active construction sites in the Gauteng province, South Africa and conducted interviews with various workers, and also distributed questionnaires. This chapter introduces the case studies, presents the data from the findings, and also analyses the data thereof.

## 4.2. Identification and categorisation of case studies

**Table 6** outlines the locations of the case studies, GPS coordinates which are presented in Universal Transverse Mercator (UTM), as well as the building type.

**Table 6** Case studies details

| Case study | Location | GPS co-ordinates in UTM | Building type |
|---|---|---|---|
| 1 | Braamfontein, Johannesburg | UTM 35 J 602449 m East, 7103162 m South | Multi-storey accommodation |
| 2 | Midrand, Johannesburg | UTM 35 J 610507 m East, 7122351 m South | Multi-storey hotel with office space |
| 3 | Rosebank, Johannesburg | UTM 35 J 604533 m East, 7107181 m South | Multi-storey office |
| 4 | Menlyn, Pretoria | UTM 35 J 628620 m East, 7147309 m South | Multi-story office, apartment & shopping centre |
| 5 | Johannesburg Central Business District (CBD) | UTM 35 J 604749 m East, 7100813 m South | Multi-story residential |

Each site was classified into one of the three categories; i.e. small, medium and large using guidelines by Wilson (2014) explained in Chapter 3. The classifications are shown in **Table 7** below.

**Table 7:** Project-sizing of case studies based on the guidelines by Wilson (2014)

| Project Aspect | Project size based on guidelines by Wilson (2014) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Case study 1 | | | Case study 2 | | | Case study 3 | | | Caste study 4 | | | Case study 5 | | |
| | S | M | L | S | M | L | S | M | L | S | M | L | S | M | L |
| Size of project team (FTE) | ** | ** | ** | ** | ** | ** | ** | ** | ** | ** | ** | ** | ** | ** | ** |
| Completion time | ☐ | ☑ | ☐ | ☐ | ☐ | ☑ | ☐ | ☑ | ☐ | ☐ | ☐ | ☑ | ☐ | ☑ | ☐ |
| Timeframe | ☐ | ☑ | ☐ | ☐ | ☐ | ☑ | ☐ | ☑ | ☐ | ☐ | ☐ | ☑ | ☑ | ☐ | ☐ |
| Complexity | ☑ | ☐ | ☐ | ☐ | ☐ | ☑ | ☐ | ☑ | ☐ | ☐ | ☐ | ☑ | ☑ | ☐ | ☐ |
| Strategic importance | ☐ | ☐ | ☑ | ☐ | ☑ | ☐ | * | * | * | ☐ | ☐ | ☑ | ☑ | ☐ | ☐ |
| Reputation importance | ☐ | ☑ | ☐ | ☐ | ☑ | ☐ | ☐ | ☑ | ☐ | ☐ | ☑ | ☐ | ☑ | ☐ | ☐ |
| Total cost | ☐ | ☐ | ☑ | * | * | * | * | * | * | ☐ | ☐ | ☑ | * | * | * |
| Level of change | ☐ | ☑ | ☐ | ☐ | ☐ | ☑ | ☑ | ☐ | ☐ | ☐ | ☑ | ☐ | ☑ | ☐ | ☐ |
| Dependencies and interrelated projects | ☑ | ☐ | ☐ | ☐ | ☑ | ☐ | ☐ | ☑ | ☐ | ☐ | ☐ | ☑ | ☑ | ☐ | ☐ |
| Overall project size | Medium | | | Medium to large | | | Medium | | | Large | | | Small | | |

***Table 7*** *Definitions:*

FTE: Full-time equivalent

S: Small-sized project

M: Medium-sized project

L: Large-sized project

*: Information confidential

**: Information not available/provided

## 4.3. Survey response rate and demographics of respondents

The researcher approached nine potential construction sites to conduct the study and managed to access five of them making it a success rate of 55%. During the site visits, ten questionnaires were distributed in each site, hence a total of 50 questionnaires.

According to Baruch (1999), the following factors should be considered when assessing a response rate levels:

- Target population: The target population was construction professions working on the construction sites visited as case studies. The target population was deemed relevant because that they work on the case studies identified.
- Number of people given forms: The researcher issued 10 questionnaire on each site during the site visits
- Questionnaires returned: The number of questionnaires returned per case study is shown in **Table 8**. All questionnaires returned were usable, there were no conditions of unusable questionnaires.

The overall response rate came out at 22% which is lower than the expected 50% response rate; however, the researcher deems them acceptable based on the factors mentioned above. Studies report that neither a low nor a high response rate guarantees neutral population estimates and also, extra work to achieve slightly greater response rate than received will only have minimal impact and hence it would be convenient to rather concentrate on assessing and utilising the data collected instead of emphasising to achieve a higher response rate (Fosnacht, K et al, 2013). A breakdown is provided in **Table 8** below.

**Table 8:** Questionnaire response rates

| Case study | Questionnaires distributed | Questionnaires answered | Response rate |
|---|---|---|---|
| 1 | 10 | 3 | 30% |
| 2 | 10 | 3 | 30% |
| 3 | 10 | 2 | 20% |
| 4 | 10 | 2 | 20% |
| 5 | 10 | 1 | 10% |

The respondents were from various professional backgrounds which included junior site manager, junior structure intern (civil engineering), site manager, general worker, safety officer, site agent, general foreman, and managing director (brickwork specialist). The respondents had a wide range of working experience. Three (27.3%) had 0-1 year of working experience, four (36.4%) had 1-3 years working experience, two (18.2%) had 10-15 years working experience, and two (18.2%) had above 15 years of working experience. All the respondents worked for South African companies. Only one respondent was working for a subcontractor; while the remaining ten were working for general contractors.

### 4.4. Types and sources of waste materials in construction sites

The main types of waste generated on the construction sites are concrete, cement, bricks, masonry, paper, glass, plastic, timber, steel, soil and cardboards as shown in **Figure 17**.

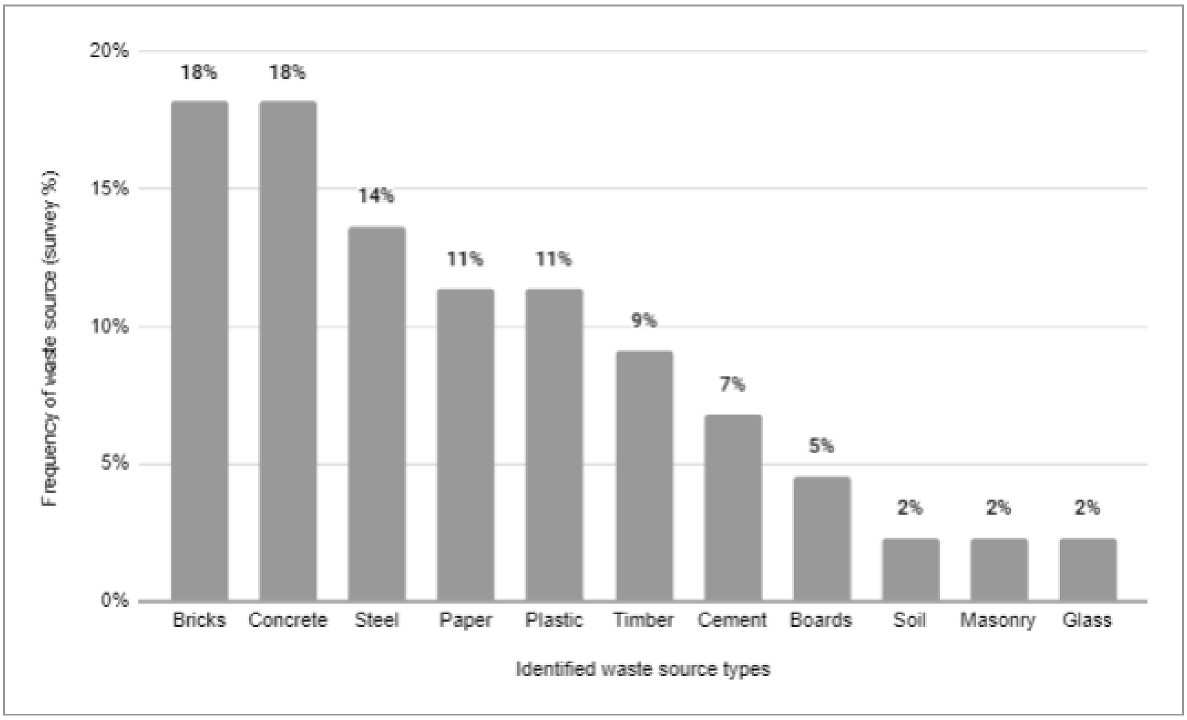


**Figure 17**: Respondents view regarding types wastes produced on the construction sites

**Figure 17** demonstrates that the questionnaire respondents identified the top three waste source material to be concrete at 18%, bricks at 18%, and steel at 14%; while glass, masonry and soil were the least selected types of waste to be produced on sites, having been selected at 2% each. Though this is the case, it does not imply that when the material is the most used it will also be the highest source of waste. **Table 9** shows the respondents´ views on the volume of various materials used on site versus the corresponding waste.

**Table 9**: Volume of materials used versus corresponding volume of waste in construction sites

| Material | Less frequently (0 - 40%) | | Average (41 - 69%) | | More frequently (70 - 100%) | |
|---|---|---|---|---|---|---|
| | Use of material | Waste production | Use on site | Waste production | Use on site | Waste production |
| Glass | 67% | 100% | 33% | 0% | 0% | 0% |
| Timber | 13% | 57% | 75% | 29% | 13% | 14% |
| Concrete | 10% | 55% | 10% | 18% | 80% | 27% |
| Ceramics | 0% | 0% | 100% | 100% | 0% | 0% |
| Metals | 38% | 43% | 0% | 29% | 63% | 29% |
| Plastic | 25% | 50% | 50% | 25% | 25% | 25% |
| Bricks | 20% | 60% | 50% | 10% | 30% | 30% |
| Masonry | 0% | 20% | 57% | 20% | 43% | 60% |

***Table 9*** *Definitions per category:*

1. Less frequently (0-40%) category
- Use of material: X% of respondents estimate that the material is used 0-40% of the times on site.
- Waste production: X% of respondents estimate that the material produces 0-40% of waste on site.
2. Average (41-69%) category
- Use of material: X% of respondents estimate that the material is used 41-69% of the times on site.
- Waste production: X% of respondents estimate that the material produces 41-69% of waste on site.
3. More frequently (70-100%) category
- Use of material: X% of respondents estimate that the material is used 70-100% of the times on site.
- Waste production: X% of respondents estimate that the material produces 70-100% of waste on site.

In **Table 9** the highest response rate in each material was considered. Concrete was estimated to be the most used material on the construction sites in the case studies, with less waste production estimates. 80% of the respondents (**Table 9**) think that concrete is used 70-100% of the time on the construction sites. However, only 27% think that that this material produces only 70-100% of waste. Instead, 55% of the respondents think that concrete produces 0-40% of waste. Meaning that the respondents think that concrete is used frequently on site but produces less waste. This scenario is also the same for metals. In **Table 9**, 63% of the respondents indicated it is used 70-100% of the times on the construction sites however only 29% think that that this material produces only 70-100% of waste. 43% of the respondents think that concrete produces 0-40% of waste. The respondents think that metal is used frequently on site but also produces less waste. These two materials (concrete and metal) are indicated to be used frequently on construction sites. However, they are the least sources of waste. This could be because the materials are used well or also due to reuse of waste material e.g. through backfilling in the case of concrete. The material with the least information is ceramics. The low response rate on ceramics could be because the construction sites were not in the finishing stage yet and therefore respondents had less information regarding the material on their current construction sites.

There is currently limited knowledge on the construction sites regarding the quantities of concrete and cementitious waste material produced. While conducting the site interviews, only one construction site, Case study 1, provided the estimated quantity of concrete waste produced, which, due to lack of information, could not be compared with other sites. The results are shown in **Table 10** below.

According to the results shown in **Table 10**, there is a gap in the recording and reporting the amount of concrete and cementitious waste material produced. It also validates the literature review which states that South Africa is lagging behind countries such as Australia with reporting amounts of concrete and cementitious waste produced. Construction sites are the primary source of the waste material and if there are no records from them then there will be no information to produce for reporting. Photographs showing the construction sites and their waste are management areas are shown in the appendix.

**Table 10**: Summary of waste produced and management of concrete waste on the construction sites

| Project aspect | Case study | Details |
|---|---|---|
| Types of waste | 1 | Bricks, concrete, paper |
| | 2 | Plastic, paper, steel |
| | 3 | Rubble, steel bar, plastic, cardboard |
| | 4 | Wood, plastic, steel rebar, paper |
| | 5 | Bricks, plastic, paper, concrete |
| Volume of concrete used | 1 | 400 cubic meters since project started |
| | 2 | 20 000 cubic meters since project started |
| | 3 | 300-350 cubic meters per day. 20 - 22 000 cubic meters since project started |
| | 4 | 300 cubic meters per day |
| | 5 | 100 cubic meters per day |
| Volume of waste concrete produced | 1 | 0.067 cubic meters |
| | 2 | Unknown |
| | 3 | Unknown |
| | 4 | Unknown |
| | 5 | Unknown |
| Handling of concrete waste | 1 | Disposal |
| | 2 | Backfilling |
| | 3 | Backfilling |
| | 4 | Backfilling and disposal |
| | 5 | Disposal |
| Other salient details | 1 | None |
| | 2 | Some sites also transport waste concrete to other sites which need backfilling material |
| | 3 | None |
| | 4 | None |
| | 5 | None |

## 4.5. Management of concrete and cementitious waste

### 4.5.1. Practices and strategies used in South Africa

During the site interviews, the workers mentioned that the re-use of waste material on site is mainly through backfilling, and the second option is disposal to landfill as shown in **Table 10**. This was further supported by the results in **Figure 18** below, where respondents indicated that they use backfilling as the primary method of managing concrete and cementitious waste material. According to the results, the waste produced on the construction sites is managed through waste disposal, recycling, and re-use, which was indicated to be the most used waste management method as shown in **Figure 18**.

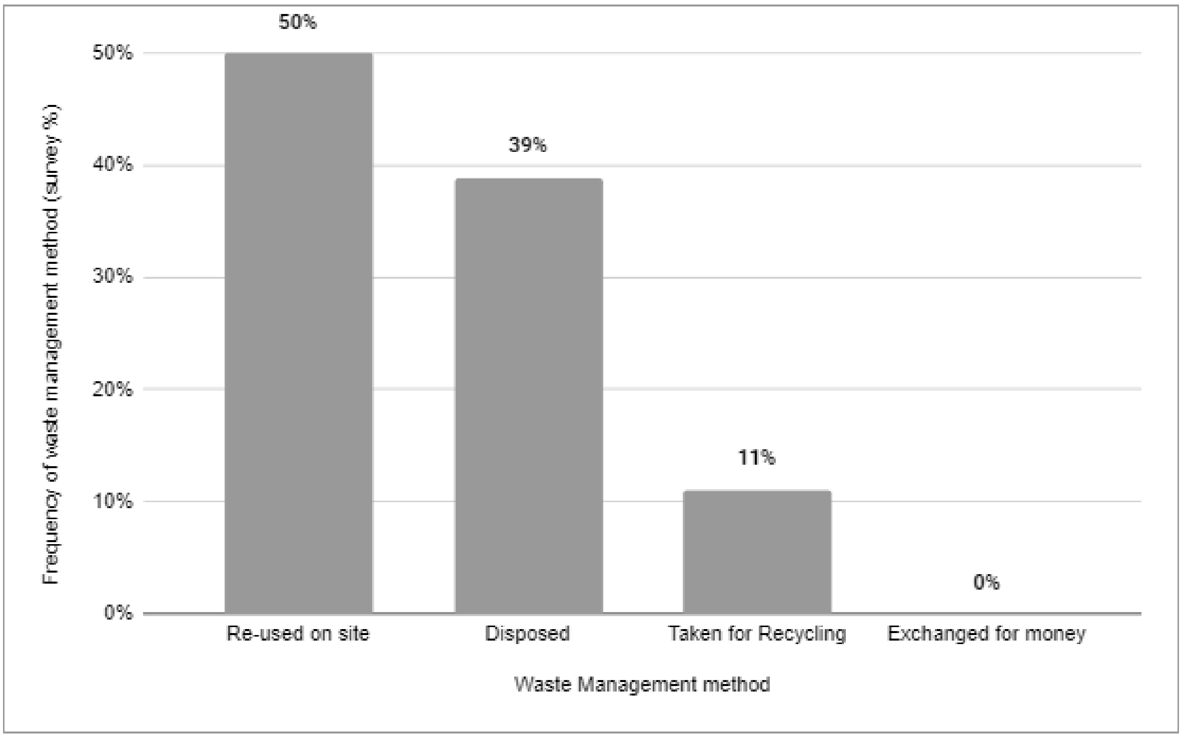


**Figure 18**: Waste management methods on the construction sites

In **Figure 18**, 50% of the respondents indicated that the waste material produced is re-used on site, through backfilling, levelling, steel fixing, and formwork erection. The material re-used includes concrete and cement-based material, soil, steel, and timber. In literature, the re-use strategy forms part of the waste management hierarchy in the technical policies noted in the State of Waste Report (SoWR).

According to the respondents, when the waste is not being re-used it is collected by a waste management company, or taken to dumping sites for disposal on landfill. As shown in **Figure 18**, disposal was the second most selected waste management method at 39%. The disposal option supports general views in the literature (Abel, 2009)[11] which points out that there are high rates of disposal on the landfill in South Africa. Only one construction site (Case study 2) indicated that when the site reaches full capacity in needing backfilling material, they transport

[11] See section 1.5

the waste concrete to other construction sites of the same company that need material for backfilling. Once this option is also exhausted, the next resort is calling a waste management company for collection or disposal on landfill.

None of the construction sites uses the exchange for money option as a waste management option hence it is at 0%. This shows that there is a gap of incentives available for management of waste material, and it also shows that there is an opportunity to improve on that.

### 4.5.2. Effectiveness of current on-site waste management

As mentioned before, the waste management plans implemented on the constructions sites include re-use of concrete through backfilling and collection by waste management companies every week. 46% of the respondents indicated that the companies have a waste management plan specifically for concrete and cementitious waste in the current projects (case studies). 27% of the respondents indicated that their companies do not have a waste management plan specifically for concrete and cementitious waste in current projects, while 27% indicated that they do not know if the companies have a waste management plan for concrete and cementitious waste or not on the current projects. The results show that some employees might not understand what a waste management plan is because all the construction sites did have waste management plans. This could be due to:

- Lack of proper communication from the employers to the employees regarding waste management on the construction sites
- Lack of development of a waste management culture in the organisation and on site

For the respondents who indicated that their companies have a waste management plan specifically for concrete and cementitious waste in their current projects, they indicated that reduce, re-use and recycle method is the most used strategies on the construction sites.

**Figure 19** shows how the respondents rate the efficiency of the companies´ waste management plans for concrete and cementitious waste used on their sites.

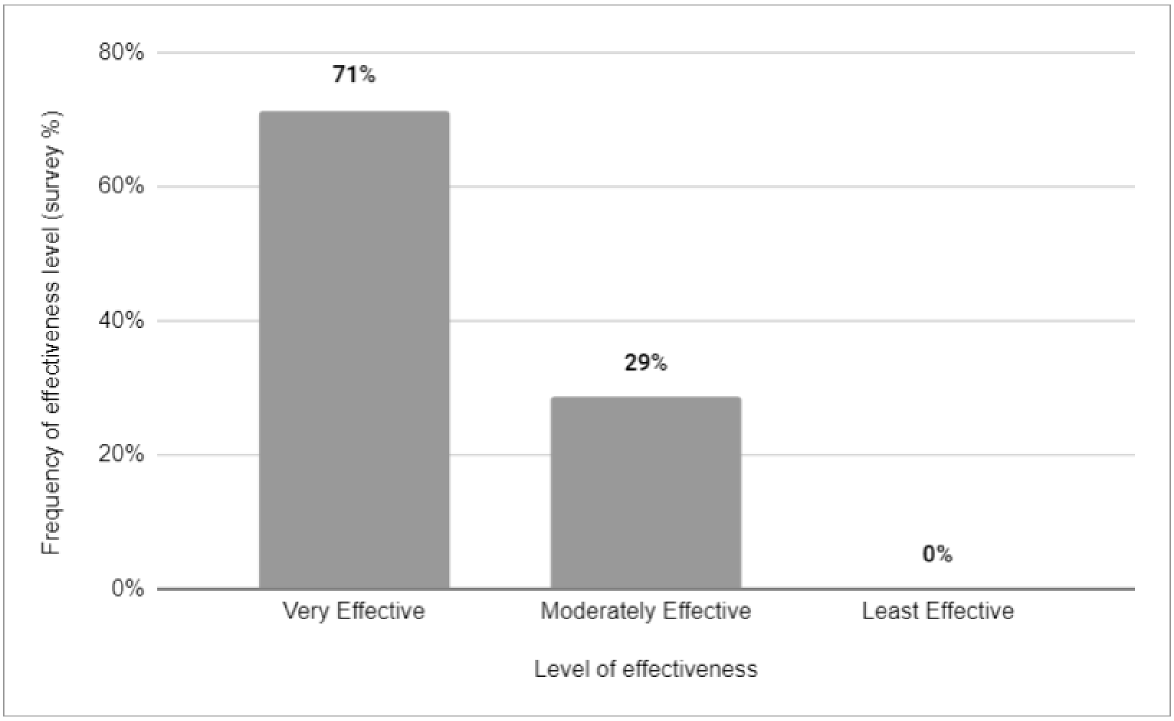


**Figure 19**: Efficiency of concrete and cementitious waste management plans

In **Figure 19**, 71% of the respondents rated the waste management plans used on their sites as very effective (80-100%) and 29% rated the waste management plans to be moderately effective (50-79%). None of the respondents thinks that the plans used on their sites are least effective (0-49%). As indicated in **Table 10**, backfilling is the main method of managing concrete and cementitious material in all the construction sites studied. The results in **Figure 19** suggests that most of the respondents think that backfilling is a very effective method for managing concrete and cementitious waste. Though some respondents indicated that the management is moderately effective, there were no suggestions on how they think the methods could be improved.

The effectiveness of managing concrete and cementitious waste material can be affected by the amount of planning done for a particular project. As shown in **Figure 2** there are various phases in a construction project cycle, **Table 11** demonstrates the views of respondents on the importance of each phase to achieve waste reduction for their projects.

**Table 11**: Importance of project phases is in achieving waste reduction

| Project phase | Very Important | Important | Neutral | Least Important | Not Important |
|---|---|---|---|---|---|
| Feasibility phase (concept) | 0% | 0% | 13% | 25% | 63% |
| Design and development phase (planning) | 11% | 22% | 11% | 44% | 11% |
| Execution phase (construction) | 78% | 11% | 11% | 0% | 0% |
| Commissioning and handover phase (finish) | 13% | 25% | 13% | 38% | 13% |

The highest response rate in each phase was considered. **Table 11** shows that 78% of the respondents selected the execution phase as the most important phase in achieving waste reduction on their construction sites. 44% think design and development phase (planning) is the least important phase, and 38% think commissioning and handover phase is also the least important. This indicates that there is a gap in the planning of waste management. Construction companies should plan for waste management of concrete and cement-based material during the design and developing phase (planning) and not wait until the execution phase to start planning. This is because planning at an earlier stage could prevent poor management strategies and practices of the waste.

### 4.5.3. Challenges with the management of concrete and cementitious waste

According to the results, concrete waste management plans implemented on the sites do not fully follow the waste management hierarchy as outlined in the SoWR (see **Figure 8**). This is because none of the construction sites mentioned how they avoid or reduce concrete waste, which is the first and most preferred waste management technique in the waste management hierarchy shown in **Figure 8**. The preferred option at the construction sites is re-use. This is the option which is well understood and practised the most when managing concrete and cementitious waste material on the construction sites.

The next two options after re-use on the waste hierarchy, recycling and recovery, are not being practised on the construction sites as well. These two options are replaced by waste management companies that collect waste from the construction sites. The practitioners on site did not portray enough knowledge on what happens to the waste after being collected by the waste management companies.

Construction practitioners also noted that there is a need to develop better methods of using recycled concrete without having a negative influence on the structures because they are not yet confident with the use of recycled concrete during construction. This is because they do not think that recycled concrete is satisfactory for construction purposes. There is insufficient knowledge regarding recycled concrete among the practitioners.

The respondents also noted that there is a need for government intervention to assist with waste management by enforcing the adoption of policies, assisting with research on more possible methods effective for waste management, assist with training where necessary, and also offering of incentives. 73% of the respondents indicated that there are no incentives (e.g. financial such as tax credits or rebates, or any other) offered to companies for developing or adopting waste management plans proposed by the government, while 27% of the respondents indicated that they have no knowledge on whether there are incentives offered to companies for developing or adopting waste management plans placed by the government or not.

4.5.4. C&D waste policies and legislation: awareness and implementation by construction practitioner´s on site

Waste management methods on construction sites are guided by different legal/technical policies shown in **Figure 20**.

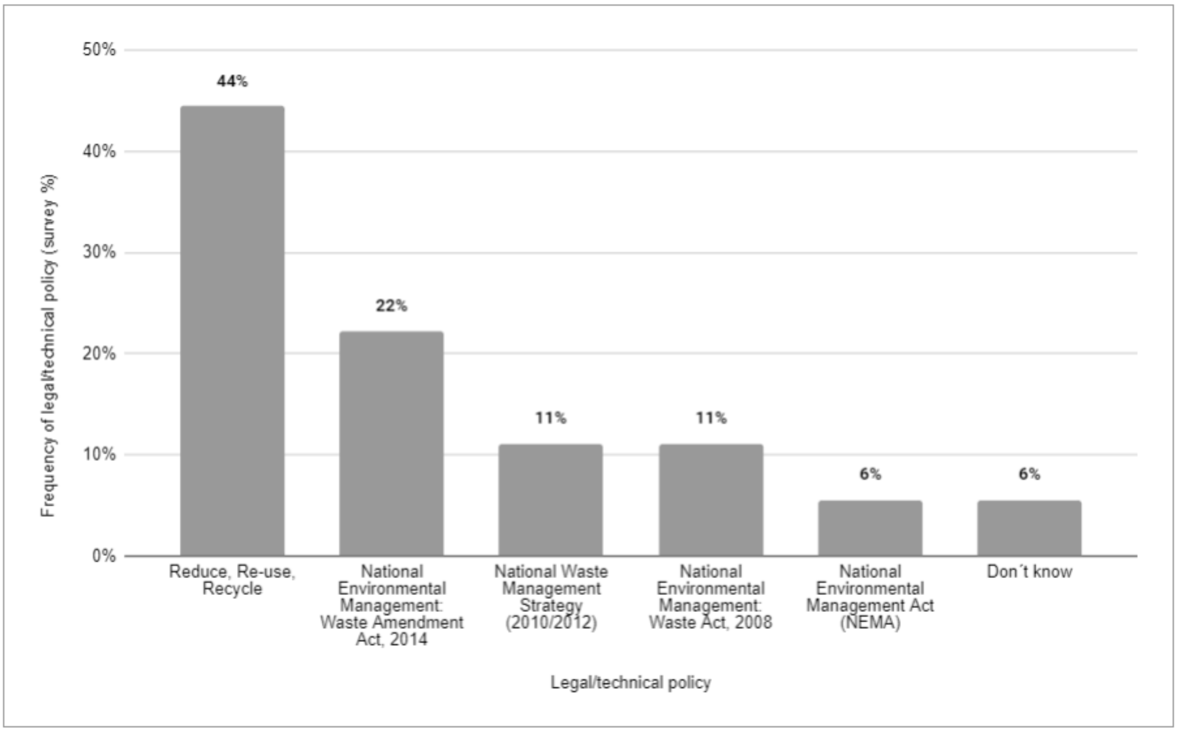


**Figure 20**: Legal/technical policies used for waste management

According to **Figure 20**, the most used legal/technical policy is reduce, re-use and recycle method which was selected by 44% of the respondents. Though this is the most selected policy, in section 4.5.3 it was shown that none of the construction sites demonstrated confidence in reducing and recycling of concrete and cementitious waste material. The re-use method is the most practised among the three. **Figure 20** also shows that there is limited knowledge of legal and technical policies outlined in the SoWR on the construction sites because, even though the other options were selected, the respondents could not demonstrate what the policies entail or how they implement the strategies outlined in the policies.

During the site interviews, the practitioners also indicated that they are not familiar with the SoWR, the fundamental document for waste management strategies in South Africa. Though this is the case, some of them are aware of the legislation outlined in the SoWR document. As highlighted earlier, the practitioners are not aware of any incentives (e.g. financial such as tax credits or rebates, or any other) offered to companies for developing or adopting waste management plans for concrete placed by the government. Furthermore, such incentives are also not clearly stated in the SoWR.

### 4.5.5. Role and involvement of the South African government in construction waste management

The government of SA took an important role in drafting the SoWR to outline goals and strategies for waste management. However, there is a lack of information transfer from the government to practitioners. It was also noted that there are no audits performed by the government on sites to ensure that practitioners comply with the requirements of SoWR. Audits can assist in recording results to track progress on the government´s 2025 national development goals[12].

According to the respondents, construction companies do not have the motivation to consider other options such as recovery and recycling before resorting to landfill. Hence they demonstrated that there is a lack of incentives for construction companies (such as exchanging waste material for money, or rewards for construction sites that manage to reduce waste to

[12] See section 1.1

certain targeted levels). This indicates that there is an opportunity to be explored by both the public and private sector for waste management of concrete and cement-based material with regards to incentives. Most of the respondents agree, see **Table 12** below, that the management of waste concrete and cementitious material is a necessary practice in the South African industry. This demonstrates a positive sign for the development of concrete and cementitious waste management as practitioners seem to be open to learning how to improve the way they manage concrete and cementitious waste material in their projects.

**Table 12**: The necessity of waste management and the adoption of waste management plans of concrete and cementitious material in the South African construction industry

| No. | Statement | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|---|
| 1 | The management of waste concrete and cementitious material is a necessary practice in the South African industry | 0% | 0% | 18% | 73% | 9% |
| 2 | The use of waste management plan for waste concrete and cementitious materials is well adopted in the South African construction industry | 0% | 0% | 64% | 36% | 0% |

Though there seems to be less knowledge on the site regarding waste management of concrete and cement-based material, 73% of the respondents agree that the management of concrete and cementitious waste is a necessary practice in South Africa´s construction industry. 64% of the respondents were neutral on whether the use of a waste management plan for waste concrete and cementitious materials is well adapted in the South African construction industry or not. They mentioned that this is the kind of information the government needs to record and report to the industry for the practitioners to be aware when they are aligned with waste management policies and when they are not aligned.

The respondents pointed out that the management of concrete and cementitious waste material can be improved if the government conducts more surveys to know the challenges faced on site and the needs of the people working on site.

### 4.6. Proposed framework on the way forward on the management of concrete and cementitious wastes in construction sites in South Africa

As highlighted in the literature review, South Africa is lagging on the availability of literature on concrete and cementitious waste material as well as its management when compared to other countries such as Australia and China. The status of the case studies in this research report might not be a reflection of other construction sites in the country as there is limited literature to support it. To improve the management of concrete and cementitious waste material, it is important to understand the condition and circumstances of current practices in place around the country. In **Figure 21**, the primary goal of the framework is improving understanding of current management and updating current strategies where necessary.

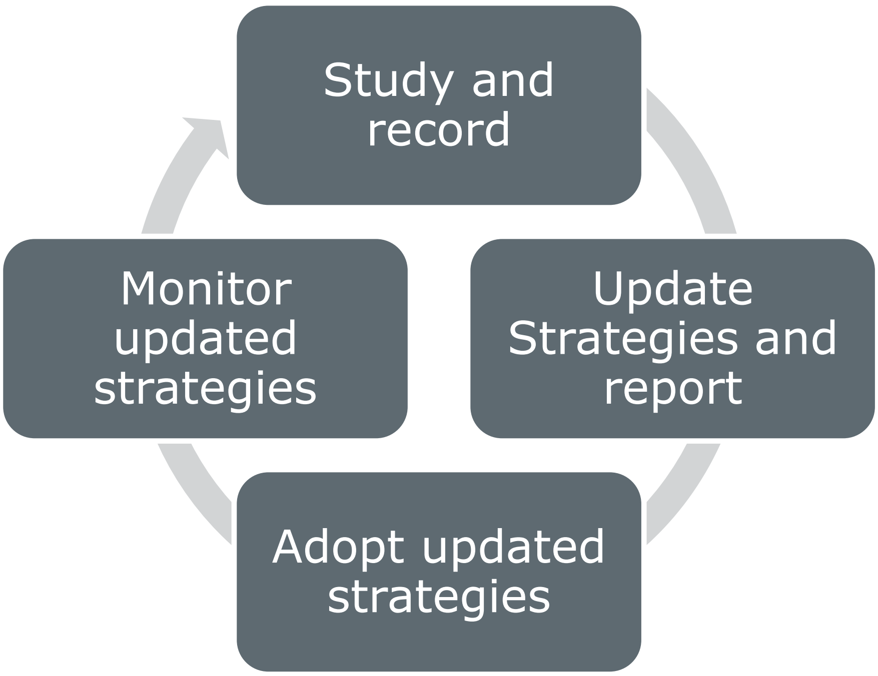


**Figure 21**: Proposed framework on the on the way forward on the management of concrete and cementitious wastes in construction sites in South Africa

#### 4.6.1 Study and record

Available studies in South Africa focus on C&D waste in general, which includes concrete and cementitious material. However, in those studies, literature does not give a view on the status of waste concrete and cementitious material. More studies need to be conducted in South Africa to understand how concrete and cementitious waste is managed in construction sites. Aspects that could be reviewed during the studies include:

- Investigate concrete and cementitious waste quantities reduced, avoided, produced, re-used, recycled and disposed of on construction sites.
- Investigate the availability of technology that could be used for waste management of concrete and cementitious material in South Africa
- The availability and use of secondary concrete and cementitious material, as well as the state of its market in South Africa. This will also be impacted by the technology available in South Africa. It will inform on the recycling levels of waste material in the industry which could in return discourage disposal on landfill
- Understand the view of construction practitioners regarding secondary concrete and cementitious material and its use.
- Investigate the availability of incentives from the government which encourages practitioners to manage concrete and cementitious waste material effectively and if they are being used in practice or not
- Investigate the relationship between the private and public sector and explore improvement on information exchange channels
- Investigate effective communication channels for the public sector, private sector, practitioners on construction sites and other stakeholders involved to understand how updates on waste management strategies could be transferred from one stakeholder to another

Conducting more studies will help in gathering and recording results, which will enable both the private and public sectors to establish better standards and modify policies based on the needs and practices implemented on construction sites currently.

#### 4.6.2 Update strategies and report

Evaluate current policies and strategies, then revise and improve them in alignment with results from studies conducted. This will also allow the government to report the status of concrete and cementitious waste material management and inform practitioners on updated policies in the SoWR document thereof. Practitioners will be informed on how to move forward based on the results reported. The key aspect is to effectively communicate the updated strategies to practitioners. It is also crucial to understand the ability of what construction practitioners can practice and what they cannot based on their circumstances.

### 4.6.3 Adopt updated strategies

For the updated strategies to be put in place, construction practitioners will need to be flexible in adapting to new changes. In that way, they will be able to adopt updated policies and recommendations reported to improve management of concrete and cementitious waste material on the construction sites. The private and public sectors should enage with SoWR updates to adopt new strategies and appropriate tools and support should be provided by the government to ensure that construction companies can adopt the strategies.

### 4.6.4 Monitor updated strategies

It is currently not clear how strategies being practised are monitored by both the public and private sectors. Performing audits could help monitor practices implemented on construction sites. This will enable an analysis of the progress in reaching goals from updated strategies and policies. While this is so, more studies will be needed to understand the impact of updated strategies on the practices and management of concrete and cementitious waste material. To ensure alignment with updated strategies, audits can serve as a tool to inspect the practices put in place and understand how aligned practitioners are with the strategies.

## 4.7. Chapter summary

The chapter presented results obtained from the sites through interviews and questionnaire surveys. While conducting the interviews with the workers, the researcher realised that most workers preferred to do interviews more than answering questionnaires. This could be due to various reasons such as literacy levels (particularly for general labourers), interpretation skills, and interviewing seemed to be less stressful than answering a questionnaire to them. It is, however, not clear if these could have affected the results.

In overall, the results show that management of waste concrete and cement-based material is mainly through backfilling and disposal on landfill. The practitioners indicted that concrete and cement-based material are not the biggest sources of waste on the sites. This is a positive indication as it means the concrete could be managed well. However, what raises concern is that once the site does not need material for backfill, some end up being disposed of in landfills. The gaps identified are that there is less knowledge on volumes of concrete and cementitious waste quantities produced and disposed in landfills.

# CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

## 5.1. Introduction

The study aimed to look at current practices and strategies for waste management of concrete and cement-based materials in the construction sector of South Africa. To achieve the objectives of the study the researcher used a qualitative approach, which was through visiting five construction sites in Gauteng province, South Africa. Data was collected through oral interviews and questionnaire distribution to construction practitioners on site. The target population was selected through non-probability and purposive sampling. Following the results interpreted and analysed in Chapter 4, this chapter provides the conclusions and recommendations of the study.

## 5.2. Conclusions

### 5.2.1. Awareness of practitioners on C&D waste policies and legislations

Practitioners are aware of the traditional waste management hierarchy (reduce, re-use and recycle) and demonstrated its use on their sites. However, they are not aware of the most updated waste management hierarchy (**Figure 8**) developed, which is the one being emphasised in the SoWR. There is a gap of knowledge on other waste management methods outlined in the waste management hierarchy from the SoWR on construction sites. In chapter 4, the respondents also indicated that they are aware of:

- National environmental management: waste amendment act, 2014
- National waste management strategy (2010/2012)
- National environmental management, waste act 2008
- National environmental management act (NEMA)

Of all the policies and legislations mentioned in the study, the practitioners provided insight regarding reduce, re-use and recycle options only. Most of the respondents from the questionnaire survey have less than three years of working experience and these are the practitioners who are recently out of higher institutions of learning. The researcher anticipated that young practitioners could be familiar with available literature regarding waste management strategies and legislature outlined in the SoWR; however, this was not the case and it is not clear which group from the construction practitioners is aware of the SoWR and its strategies.

Nonetheless, the SoWR is a good tool for construction practitioners to familiarise themselves with legislature and policies for waste management in South Africa.

### 5.2.2. Comparison of waste management strategies in South Africa with those in other countries

The researcher considered waste management strategies in South Africa, as well as in four international countries (developed and developing); China, Australia, Germany and Kenya. Australia, China and Germany are ahead of South Africa and Kenya with regards to available information being reported on waste quantities of concrete and cementitious waste material and other waste types. This is because more studies are being conducted in those countries, hence contributing to the availability of knowledge and information that practitioners on construction site have regarding waste production and management.

What is common in all the countries, including South Africa, is that the strategies of waste management are based on the waste management hierarchy models. The models are named differently from one country to another. The South African SoWR refers to the model as the waste management hierarchy, China refers to it as the new waste management paradigm, Australia the waste hierarchy, Germany the waste management hierarchy and in Kenya, it is the integrated waste management hierarchy. Though they are named differently, they are all used as a leading tool for developing waste management plans and they echo the same message.

The models promote waste reduction and avoidance as the most preferred method in managing waste material and they discourage disposal of waste material, making this method the least preferred option in the hierarchy. Waste producers are thus encouraged to dispose of minimum quantities as much as possible. China, Australia and Germany have more advanced practices of recycling and recovering waste, however, this is not the case for Kenya, and South Africa. For South Africa, this is also supported by the results from the case studies of this research. The lack of recycling and recovering waste is due to various reasons such as lack of awareness and knowledge, lack of funding and slow adoption of modern technological options.

### 5.2.3. Waste management strategies on construction sites

The primary tool for waste management on the construction sites is through the traditional waste hierarchy and the most practised option is re-use. Practitioners indicated that waste is also reduced however it was not clear what strategies are implemented to reduce waste, while the recycle method is not practised at all. The practitioners pointed out that the recycle method is practised by the waste management companies that collect the waste from their sites. On the construction sites there is no record keeping of waste quantities they produce, reuse and dispose of. Construction sites are the primary sources of waste and as such would be able to provide more accurate data of waste produced and how it is managed. There is an opportunity for the government to encourage recording waste quantities on construction sites for incentives in return.

Countries such as China are ahead with technological innovations for recycling and recovering concrete and cementitious waste material and the use of recycled material by construction practitioners is well adopted. As noted in the results, practitioners in South Africa are not yet comfortable with the use of recycled material and therefore there is a need to transfer more information for better understanding. Practitioners on the construction sites do not know of any available incentives offered for concrete and cementitious waste material. Inadequate knowledge of practitioners on incentives limit their options for managing waste and consequently, they resort to the landfill before exploring other available options.

#### 5.2.4. Management of concrete and cementitious waste material on construction sites

There is limited information regarding quantities and management of concrete and cementitious material waste produced in South Africa, and this created a challenge for this study in particular. The results demonstrated that practitioners are aware of the traditional waste management hierarchy (reduce, reuse and recycle) and they manage concrete and cementitious waste on their construction sites mainly through the reuse method by backfilling. Once the construction sites use backfilling to their maximum ability, the waste is either collected by waste management companies or disposed on landfill.

## **5.3. Recommendations**

### 5.3.1. Way forward on the management of C&D waste in South Africa

#### *5.3.1.1. Policies and legislations*

The SoWR is the source for waste policies and legislations however the challenge is ensuring that practitioners are aware of it and what it contains. The waste hierarchy outlined in the SoWR should be emphasised more and encouraged on construction sites. Practitioners should, in particular, be encouraged to practice waste avoidance and waste reduction as their first options. These are strategies that should be outlined during design and development (planning) phase of a construction project to allow appropriate planning time. Practitioners should further be discouraged to resort to waste disposal before exploring other possible options for managing waste. This involves setting policies and legislations that set targets of decreasing waste disposed on landfill by introducing taxes on waste disposal. The policies and legislation need to encourage practitioners to quantify different types of waste produced on construction sites. This will improve the data available in South Africa and also enable analysis do be done with the most recent recorded information.

#### *5.3.1.2. Education of stakeholders*

Stakeholders involved in construction must be educated on the importance of C&D waste management as the government aims to improve sustainability in South Africa. Stakeholders that need to be educated on waste management include construction practitioners, and in particular the Environment, Health and Safety (EHS) practitioners. This can be done through workshops, campaigns and creating website groups. The government should ensure that EHS practitioners are updated on the latest policies and legislations in the SoWR. This will avoid information gaps such as having an updated waste management hierarchy in the SoWR with practitioners not fully familiarised with it for practice.

None of the construction sites in the case studies indicated how they avoid or reduce concrete and cementitious waste material. To decrease the amount of waste going on landfill practitioners need to be educated on the importance of waste reduction and avoidance, and that waste management on sites should be emphasised more. As shown in the case studies, practitioners are not fully involved with recycling and recovering of concrete and cementitious waste. There is an opportunity for the government to introduce incentives to encourage other available methods of managing the waste before resorting to landfill.

The practitioners have an interest in managing concrete and cementitious waste material efficiently and effectively. This was demonstrated by the positive response from the results.

#### *5.3.1.3. Implementation and monitoring*

EHS practitioners should be responsible for planning, managing and implementing strategies on their respective construction sites based on policies in the SoWR. They should also be responsible for educating and spreading the knowledge to other professions involved in their projects as well to ensure that their teams are working towards the same goal regarding waste management.

The policies and strategies outlined in the SoWR should require EHS practitioners to submit annual waste reports where data can be populated and analysed for reporting and updating the SoWR. The reports could contain information such as strategies planned to manage waste, how much waste was produced, types of waste produced, how the waste was managed, and lessons learned for the future. This could strengthen the availability of literature on C&D waste and could also assist the government to audit the performance of policies and legislations outlined in the SoWR on construction sites.

Waste management should be considered during the design and development (planning) phase. This will enable EHS teams to indicate how they develop waste strategies for an upcoming project and how it will help improve and tighten waste management strategies on their projects. Though there is information on C&D waste on a national level in the SoWR, the information could be more enhanced if it is monitored starting from the construction sites because that is where the waste is primarily produced. The practitioners indicated that they use concrete and cementitious waste for backfilling, however when they don´t need backfilling material anymore, the waste gets disposed or collected by waste management companies. There are no records of quantities disposed on landfill.

### 5.3.2. Final conclusions and recommendations for future studies

The construction industry is one of the main contributors to waste in South Africa. As it stands, there is limited literature in the country regarding concrete and cementitious waste material. Construction sites should be encouraged to record estimates of concrete and cementitious waste material that is produced, reused and disposed on landfill. None of the sites assessed uses recycled concrete and therefore it might be beneficial to conduct studies regarding the thoughts of construction practitioners on the use of recycled concrete in South Africa. More studies should be conducted to understand how concrete and cementitious material waste is managed in other construction sites since this study only considered five case studies. This would be a way of understanding and filling in the gaps of the limited literature on the waste composition and how much of it gets to the landfill.

This study received only 28% respondent rates of the questionnaires distributed mainly due to time constraints and lack of access to more construction sites. To improve the return rate of information for future studies, it is recommended that more time is allocated for the process of requesting access to construction sites. With more construction sites accessed more information will be obtained. Furthermore, it is also recommended that future studies rely more on direct interviews instead of written questionnaires to increase the return rate of the research. Though it is recommended to rely more on direct interviews, it is still recommended to use written questionnaires as well, to gather information using multiple mediums and thus increase the rate of return. This is because, in the interviews that were conducted for this study, contractors could not provide sufficient information particularly on concrete and cementitious waste produced on their sites, and how much of it is disposed.

This study did not include a comparative assessment with other countries (developed and developing) on the level of contractor attitudes, except with Kenya as discussed in Chapter 2. More studies from other countries, both developed and developing, should be conducted to make a comparative assessment of how contractors manage concrete and cementitious waste in other countries. The studies should also investigate whether contractors recycle concrete and cementitious waste and also understand what the contractor´s views are on the use of recycled concrete and cementitious material for the construction of new infrastructure/projects. This study did not investigate the role of the construction sector in self-regulating and developing organisational cultures that promote responsible generation and management of concrete and cementitious waste within the industry. Future studies are recommended to research how the industry and contractors, in particular, view self-regulating and developing cultures that promote responsible generation and management of concrete and cementitious waste.

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## APPENDIX

## Submission of research report for examination form

**Faculty of Engineering and the Built Environment**

Private Bag 3, Wits 2050, South Africa * Telephone (011) 717 – 7007 * Fax: (011) 717 7009

WITS UNIVERSITY

### SUBMISSION OF THESIS/DISSERATIO/RESEARCH REPORT FOR EXAMINATION

1. Name: FRIEDA MOSHADI
2. Surname: MOGODI
3. Student No: 609483
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   E-mail Address: shadimogodi@gmail.com

5. I hereby submit my ~~Thesis~~ / ~~Dissertation~~ / Research Report (delete whichever is not applicable).
6. I have checked all copies of my Thesis / Dissertation / Research Report and declare that no pages are missing or poorly reproduced.
7. Number of copies: 2 (bound and single sided) 1 (pdf)
8. I confirm that my signed declaration in terms of Rule G27 is included in each copy of the Dissertation / Research Report / Thesis.
9. Title of submitted Dissertation / Research Report / Thesis

   ASSESSMENT OF PRACTICES AND STRATEGIES FOR WASTE MANAGEMENT OF CONCRETE AND CEMENTITIOUS MATERIALS IN SOUTH AFRICA

10. PhD students first registered as of 2014 are required to have submitted a paper for publication. Please indicate whether you have done so and attach a copy of the paper.
    All other higher degree students only need to indicate whether they have submitted/published a paper YES NO
11. Did your research involve animal experimentation or human participants as defined in A.4 of the Senate Standing Orders on Higher degrees? YES NO
    If **YES**, please certify that clearance was obtained from the relevant Ethics committee
    Clearance Number: CEECC-(609483-2018)
12. I understand that I may not graduate unless my University fees have been paid in full and I have no Library holds.
13. Name of Supervisor(s)

    Dr. MIKE OTIENO School: CIVIL & ENVIRONMENTAL ENGINEERING

    School:

Signature of Candidate:

Date: 14 MARCH 2020

FACULTY STAMP

## Ethics clearance certificate

**Assessment of Ethics of Research Protocols in which humans are involved**

**Civil and Environmental Engineering Ethics Clearance Certificate No: CEECC-(609483-2018)**

**Researcher**: Moshadi Mogodi **Student No.** 609483

All research in which humans are involved either as informants or subjects (carried out in the University by undergraduates, postgraduates, staff or affiliated staff in the name of the University) need to respect the rights of individuals by ensuring that:

- the informant or subject has consented to the research without coercion;
- the questions posed are not insulting or embarrassing;
- confidential matters that could place the informant in an embarrassing, false or compromising position vis-à-vis authorities, are handled circumspectly;
- the privacy and wishes of informants are respected, i.e. anonymity of the informant is maintained if required;
- the informant is informed as fully as possible as to the aims and possible implications of the research.

For MSc researchers on a half coursework half research (MSc 50/50) or the Master of Engineering (MEng) program, the assessment is carried out by the School Ethics Committee within the respective Schools.

The research proposal by Moshadi Mogodi includes the acquisition of information by the use of questionnaires and the School Committee assessed the proposed research protocols on 03 August 2018.

The committee found the research proposal to meet all the requirements set by the Human Research Ethics Committee (HREC Non-Medical) of the University of the Witwatersrand.

Prof. John Ndiritu
Chair, School of Civil and Environmental Engineering Ethics Committee

**Photographs from Sites**

Site 1 photographs

**Figure 22**: Waste concrete and bricks on the site during construction


**Figure 23**: A view of the bin on site, which contained a mix of bricks, plastic and paper

Site 2 photographs

**Figure 24**: An aerial view of the site

**Figure 25**: View of the bin area with waste steel, plastic and paper, and concrete sorted

**Figure 26**: A view of areas trenches where waste concrete is used for backfill

Site 3 photographs

**Figure 27**: A view of the waste area which includes steel, plastic and paper


**Figure 28**: Waste concrete, bricks and soil to be used as backfill material

Site 4 photographs

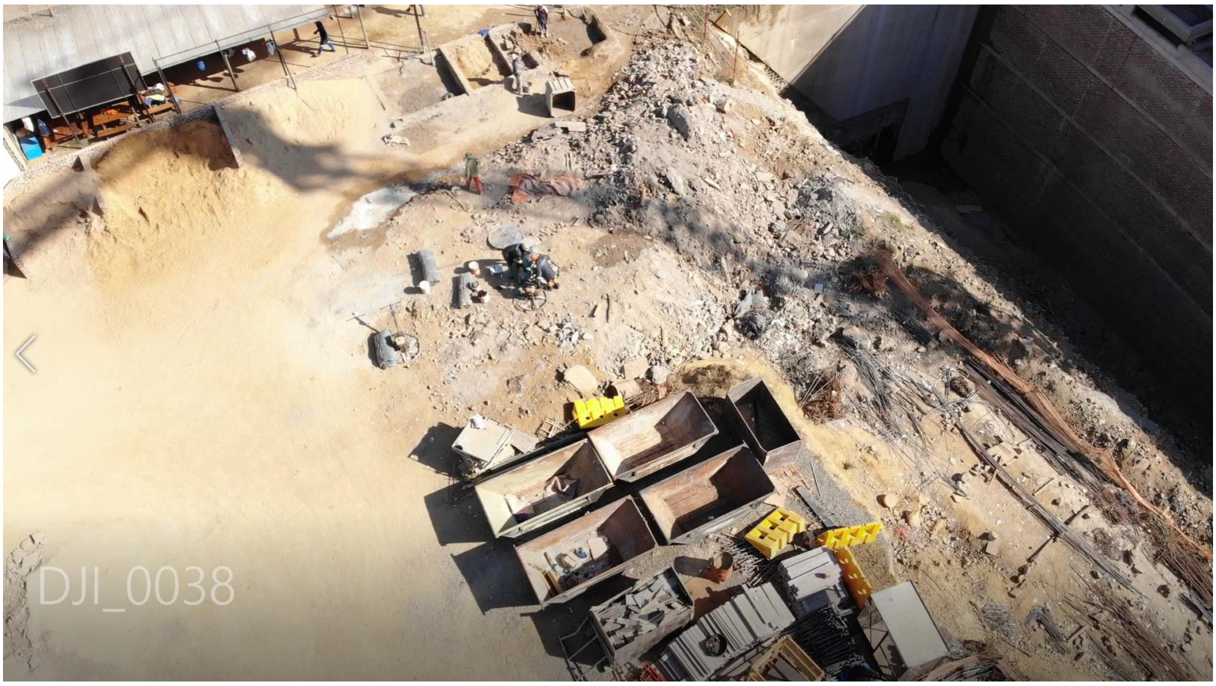


**Figure 29**: An aerial view of the bin area, bins were emptied.

**Figure 30**: A view of trenches that will need backfilling with concrete and cement-based material.

Site 5 photographs

**Figure 31**: A view of waste material which included a mix of concrete, bricks, paper and plastic

**Figure 32**: Waste concrete and bricks inside the building being constructed

# Sample Questionnaire

## Questionnaire

The following survey is conducted by Miss Moshadi Mogodi, an MSc Engineering (Civil) student in the School of Civil and Environmental Engineering at the University of the Witwatersrand, Johannesburg.

**Title of Study**: Assessment of Practices and Strategies for Waste Management of Concrete and Cementitious Materials in South Africa.

**Aim of study**: To analyse, critically review and examine current practices and strategies for waste management of concrete and cement-based material in the construction industry, South Africa.

**Ethical Considerations for the study:**

- Participants´ identity will be kept anonymous.
- Participants allowed to withdraw from the study at any point
- Data submitted by the study will be confidential and not be changed to suit the expectations of the researcher
- Data submitted will be secured by the researcher for the purpose of the study and not be made readily available to the public

**Instructions**

- Please answer all questions in the questionnaire.
- Participation is voluntary.
- Participants may withdraw from the study at any time and there will be no penalties for either refusal or withdrawal from the study.

**Demographic Questions**

1. How many years of experience do you have in the construction industry?

| | |
|---|---|
| 0 – 1 Year | |
| 1 – 3 Years | |
| 3 – 7 Years | |
| 7 – 10 Years | |
| 10 – 15 Years | |
| Above 15 Years | |

2. What is your current job position?

| |
|---|
| |

3. Please choose the description that best suits your company.

| | |
|---|---|
| Consulting | |
| Principal Contractor | |
| Sub-Contractor | |

If other, please specify:

| |
|---|
| |

4. Is your company local (South African) or international (non-South African)?

| | |
|---|---|
| Local | |
| International | |

4.1.If your company is international, please specify country of origin.

| |
|---|
| |

**Survey Questions**

1. What types of waste do you generate on your construction site?

| |
|---|
| |
| |
| |
| |
| |

2. What happens to the waste generated on your construction project?

| | |
|---|---|
| Disposed | |
| Re-used on site | |
| Taken for Recycling | |
| Exchanged for money | |
| Other, please specify below: | |
| | |
| | |

3. Which legal or technical policy does your current project follow?

| | |
|---|---|
| National Waste Management Strategy (2010/2012) | |
| National Environmental Management: Waste Act, 2008 | |
| Reduce, Reuse, Recycle | |
| National Environmental Management Act (NEMA) | |
| National Environmental Management: Waste Amendment Act, 2014 | |
| Company developed legal or technical policy | |
| None of the above | |

4. What other legal or technical policies for waste material do you know?

| |
|---|
| |
| |
| |
| |
| |

5. What is the estimated proportion of construction materials used on your construction site? Choose from the list below.

| Material | Less (0-40%) | Average (41-69%) | More (70-100%) |
|---|---|---|---|
| Glass | | | |
| Timber | | | |
| Concrete | | | |
| Ceramics | | | |
| Metals | | | |
| Plastic | | | |
| Bricks | | | |
| Masonry | | | |

6. From the above mentioned, what is the proportion of waste each material produces on your site?

| Material | Less (0-40%) | Average (41-69%) | More (70-100%) |
|---|---|---|---|
| Glass | | | |
| Timber | | | |
| Concrete | | | |
| Ceramics | | | |
| Metals | | | |
| Plastic | | | |
| Bricks | | | |
| Masonry | | | |

7. Is any of the waste material produced (as indicated above) re-used and/or recycled on site?

| | |
|---|---|
| Yes | |
| No | |
| Don't know | |

7.1.If yes, please indicate the waste type and recycling method

| |
|---|
| |
| |
| |
| |
| |

7.2.If no, what happens to the waste material

| |
|---|
| |
| |
| |
| |
| |

8. Does the company have a waste management plan specifically for concrete and cementitious waste in your current projects?

| | |
|---|---|
| Yes | |
| No | |
| Don´t know | |

8.1. If yes, please elaborate on the waste management plan below.

| |
|---|
| |
| |
| |
| |
| |

8.2. In your opinion, how efficient do you think the waste management plan is in reducing the waste produced on site?

| Least Effective | Moderately Effective | Very Effective |
|---|---|---|
| 0-49% | 50-79% | 80-100% |
| | | |

9. Below are phases of a project life cycle. In your opinion, which phase is the most effective in reducing concrete and cementitious waste material for the company?

| | |
|---|---|
| Feasibility phase (concept) | |
| Design and development phase (planning) | |
| Execution phase (construction) | |
| Commissioning and handover phase (finish) | |
| None | |

10. How important do you think each phase is in achieving waste reduction for the project? Please rate all the phases individually.

| Level of importance / Phase | Very Important | Important | Neutral | Least Important | Not Important |
|---|---|---|---|---|---|
| Feasibility phase (concept) | | | | | |
| Design and development phase (planning) | | | | | |
| Execution phase (construction) | | | | | |
| Commissioning and handover phase (finish) | | | | | |

11. Are there any incentives (e.g. financial such as tax credits or rebates, or any other) offered to companies for developing concrete and cementitious waste management plans, or for adopting concrete and cementitious waste management plans placed by the government?

| | |
|---|---|
| Yes | |
| No | |
| Don't Know | |

11.1. If yes, please list the incentives below

| |
|---|
| |
| |
| |
| |
| |

12. How effective do you think the management of concrete and cementitious waste materials (policies and practices) is in the South African construction industry?

| Least Effective | Moderately Effective | Very Effective |
|---|---|---|
| 0-49% | 50-79% | 80-100% |
| | | |

13. Please indicate your opinion in relation to the statements below.

| | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|
| The management of waste concrete and cementitious material is a necessary practice in the South African industry | | | | | |
| The use of waste management plan for waste concrete and cementitious materials is well adopted in the South African construction industry | | | | | |

14. How do you think the management of waste for concrete and cementitious material can be improved to accomplish maximum results?

| |
|---|
| |
| |
| |
| |
| |

15. For any further comments regarding concrete waste management in South Africa please mention them below:

| |
|---|
| |
| |
| |
| |
| |